PROJECTS ■ THEORY ■ APPLICATIONS ■ CIRCUITS ■ TECHNOLOGY

NUTS AND VOLTS

EVERYTHING FOR ELECTRONICS

www.nutsvolts.com
September 2009

BUILD YOUR OWN DUNGEON KEEPER

Das BlinkenBoard Candelabra

✦ **Bicycle Gear Position Indicator**
Keep your eyes on the road instead of your chain.

✦ **Experiments with Alternative Energy**
External conditions that affect solar panels.

✦ **Magnetic Pendulum**
Get into the swing of magnetism at work.

✦ **The ReFUSEable Box**
Programmable relay for troubleshooting.

U.S. $5.50 CANADA $7.00
09>
0 74470 89295 3

Welcome to the Digital Edition of Nuts & Volts

Nuts & Volts Digital Edition is a replica of the print edition of *Nuts & Volts*. It is an experience much like the print magazine with added benefits, such as online searching, embedded multimedia, and printing. *Nuts & Volts* Digital Edition can be viewed from any web browser (i.e., Internet Explorer, Firefox, Safari, etc.) and requires no downloading of software giving you instant access to your entire *Nuts & Volts* collection!

Members of the Preferred Subscriber network can view all digital issues dating back to January 2004! To learn more about this program and upgrade, place a New order or go to the Renew page in our Subscriber Services section. Be sure to mark the box for the Preferred Subscriber Network status. Standard Subscribers will only be able to view issues from their subscription start date forward.

Guide for using Nuts & Volts Digital Edition

Page Navigation: Use the arrow buttons to turn to the next, previous, first and last pages.

Pointer Icon: Click to zoom in for a closer look.

Hand Icon: Click to open a new window for more information.

Contents — **Contents:** Show the table of contents for quick access to a particular story.

Pages — **Pages:** Display the 'thumbnails' for each page in this digital edition.

Search — **Look It Up:** Find the pages containing any word or phrase.

Links — **Links:** List all of the web links (URLs) and E-mail addresses.

Archives — **Archives:** View all available archived issues.

Share — **Share With Friends:** E-mail an article to a friend.

Download — **Download:** Save a local version directly to your computer for off-line viewing.

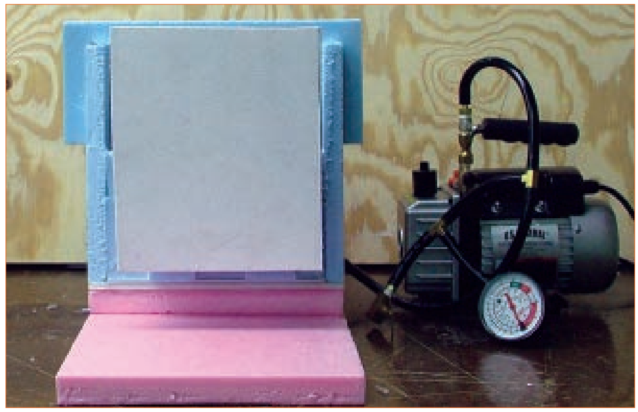
Settings — **Personalize It:** Adjust the page view size to suit your preferences.

Print: Click this icon for easy article portability.


Input Serial Data
Normal/Inverted
Outputs for
Buzzer or Relay
Stays crunchy
in milk
2X16 and 4X20
Serial Displays
3 wire hookup
2X16 and 4X20
Serial Displays
Many Popular Sizes &
Colors. 1x16, 2x16,
2x20, 4x20. Red,
Blue and Green
Make your own
custom characters
254 Backlight Levels
TTL user Outputs
RS232 and TTL Inputs
9600/2400 Baud
RoHS Compliant
Visit BasicX.com
Easy to use!
Priced from $34.95!
Connect to
Micro or PC


MGM
Let your geek shine.
Meet Vanessa Carpenter and Dzl Møbius, SparkFun customers and developers of the Critical Corset. Using a heart rate monitor, an Arduino, and a cleverly hidden air pump system, Vanessa and Dzl designed a corset that explores the rules of attraction. As the user's heart rate increases, the corset gently tightens, creating a more confident posture.
Whether you need a heart rate monitor or just a handful of LEDs, the tools are out there. Create a project you'll love, and let your geek shine too.
sparkfun ELECTRONICS
Sharing Ingenuity
WWW.SPARKFUN.COM
©2009 SparkFun Electronics, Inc. All rights reserved. All other trademarks contained herein are the property of their respective owners. Arduino is released under the Creative Commons Attribution Share-Alike 3.0 License.
For more info on Vanessa and Dzl's project visit www.illutron.dk.


Page 39


Page 62

Projects & Features

Departments

Columns

Nuts & Volts (ISSN 1528-9885/CDN Pub Agree #40702530) is published monthly for $24.95 per year by T & L Publications, Inc., 430 Princeland Court, Corona, CA 92879. PERIODICALS POSTAGE PAID AT CORONA, CA AND AT ADDITIONAL MAILING OFFICES. POSTMASTER: Send address changes to **Nuts & Volts, P.O. Box 15277, North Hollywood, CA 91615** or Station A, P.O. Box 54, Windsor ON N9A 6J5; cpcreturns@nutsvolts.com.

by Bryan Bergeron, Editor

DEVELOPING PERSPECTIVES

Virtual Instruments: Cost Savings or Illusion?

Although it's possible to make do with a multi-function DMM, sooner or later, you'll want to add an oscilloscope to your arsenal of test equipment. So, what's your best option — a traditional, stand-alone instrument or a virtual instrument that requires a PC for signal processing and display?

Entry-level virtual oscilloscopes are relatively inexpensive if you already have a suitable PC. My favorite virtual oscilloscope for quick and dirty audio frequency work is the Parallax oscilloscope (**www.parallax.com**). I keep the compact, rugged, two-channel hardware tucked in a drawer until I need it for a measurement. The eight-bit unit — which operates at 500 thousand samples per second (Ks/s) and accepts a 20 Vpp signal — is perfect for most 12 VDC applications.

The software is easy to operate (see **Figure 1**), and the USB-powered hardware unit comes with a set of well-engineered color-coded probes. Moreover, at $140, the virtual instrument has paid for itself many times over.

Another of my favorite entry-level virtual instruments is the TrueRTA oscilloscope and spectrum analyzer (**www.trueaudio.com**). The user interface (see **Figure 2**) is more feature-laden than the Parallax scope, and the spectrum analyzer is both powerful and easy to set up and use. Best of all, the fully functional, entry-level program is free. You can use it as-is or, if you need higher resolution, you can upgrade to a higher-resolution version.

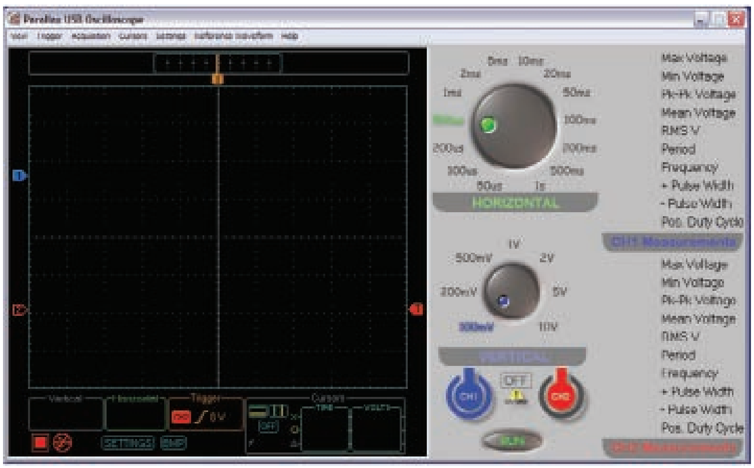


FIGURE 1. Parallax virtual oscilloscope interface.

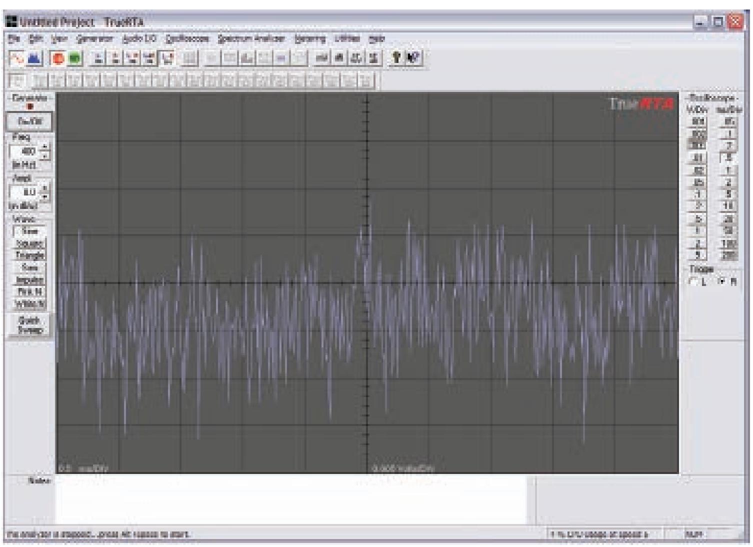


FIGURE 2. TrueRTA virtual oscilloscope interface.

TrueRTA requires a high quality audio card for signal processing. Input and output is via the speaker and microphone connections on your PC. TrueRTA is designed for audio work (as opposed to audio frequency work), such as establishing the frequency response of a speaker system. Although you could connect signal sources other than a microphone to the input of your sound card, you risk frying your computer hardware.

A recent addition to my virtual toolkit is the USB-1208FS and TraceDAQ software (**www.mccdaq.com**). On paper, the unit is impressive: 12-bit; USB-powered; eight single-ended analog inputs; and two 12-bit analog outputs. With a sample rate of 50 thousand samples per second, the USB-1208FS is limited to audio frequency work.

The $190 instrument ships with the 'standard' version of TraceDAQ software which provides a crippled function generator, rate generator, oscilloscope, and strip chart. The crippling is bizarre. For example, the function generator synthesizes the positive side of a sine wave.

More importantly, the software doesn't enable you to set up a sine wave generator, inject the signal into a circuit, and simultaneously monitor the signal with the oscilloscope application. For another $200, you can get a full version of the software — and the other side of the sine wave.

Compared with my other entry-level virtual instruments, the user interface is very 90's as in **Figure 3**. The hardware is similarly Spartan, in that the unit does not ship with leads. Moreover, the initial setup and calibration involves a contorted routine involving multiple jumpers and interacting with a calibration program.

Given the complexity of setup and use, I've

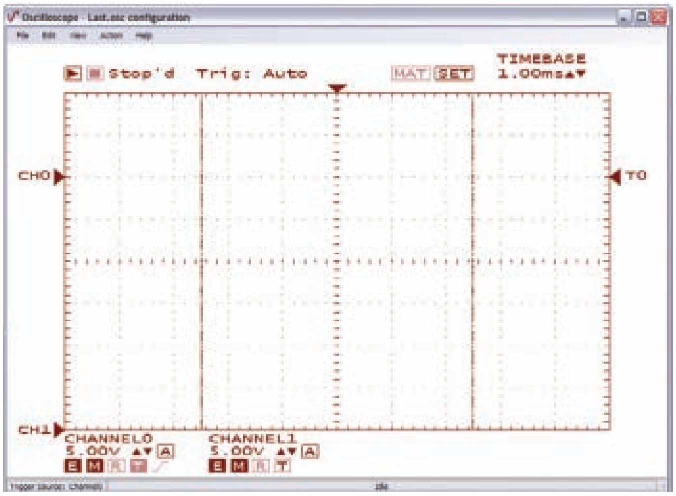


FIGURE 3. TraceDAQ interface to USB-1208FS.

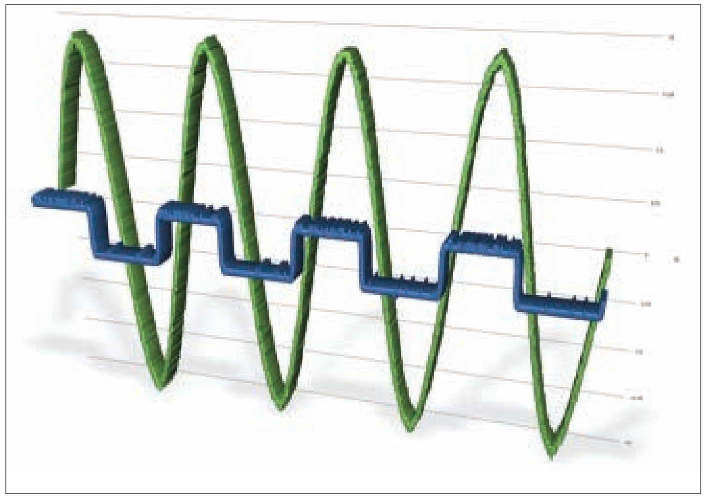


FIGURE 4. Data imported from Tektronix scope and plotted in spreadsheet program.

relegated this virtual instrument to tasks requiring a chart recorder.

For most of my work, I use a dual trace digital Tektronix scope with compensated leads and probes that I picked up from eBay a few years ago. It allows me to avoid the hassle of tugging around a laptop, and of constantly untangling makeshift leads and USB cables. A surplus memory module that I purchased from Naptech Instrument Supply (**www.naptech.com**) enables me to capture and export the data into a spreadsheet for graphing, as in **Figure 4**.

In summary, virtual instruments — like traditional instruments — vary in cost, quality, and useability for a particular task. Don't assume that more expensive or greater resolution is better. If you occasionally need an oscilloscope and work with circuits operating at a few hundred kHz or less and have a PC or laptop next to your workbench, then consider the Parallax scope.

On the other hand, if you work mainly with RF circuits, frequently use multiple instruments simultaneously, need mobility, or spend hours at a time diagnosing circuits, then consider a used traditional scope with a good set of leads. **NV**

DEVELOPMENTS TO DEVELOPMENT

I enjoyed Chuck Hellebuyck's article, *Improving the PICKit 2 Development Board* in the July '09 issue and would like to add a few things I have done with my boards. Cutting the jumper for J1 through J4 and adding header pins is a good idea, but I used SIP sockets instead. This allowed me to connect the LEDs with a jumper wire, as well as disconnect the LEDs. It also allowed me to pull the jumper and run a wire from the LED to another pin on the PIC.

I found that the All Electronics snappable 30-pin SIP socket (.1" centers [SIP-30] $1.20 each, 10 for $1.05) were

NUTS AND VOLTS
EVERYTHING FOR ELECTRONICS

Published Monthly By
T & L Publications, Inc.
430 Princeland Ct.
Corona, CA 92879-1300
(951) 371-8497
FAX **(951) 371-3052**
Webstore orders only **1-800-783-4624**
www.nutsvolts.com

Subscriptions
Toll Free **1-877-525-2539**
Outside US **1-818-487-4545**
P.O. Box 15277
North Hollywood, CA 91615

FOUNDER/ASSOCIATE PUBLISHER
Jack Lemieux

PUBLISHER
Larry Lemieux
publisher@nutsvolts.com

ASSOCIATE PUBLISHER/ VP OF SALES/MARKETING
Robin Lemieux
display@nutsvolts.com

EDITOR
Bryan Bergeron
techedit-nutsvolts@yahoo.com

CONTRIBUTING EDITORS
Jeff Eckert, Russ Kincaid, Vern Graner, Fred Eady, Joe Pardue, John Gavlik, Vaughn Martin, Dan Gravatt, Tony Gasparovic, Ron Newton, Chuck Hellebuyck, Jon Williams, Paul Verhage

CIRCULATION DIRECTOR
Tracy Kerley
subscribe@nutsvolts.com

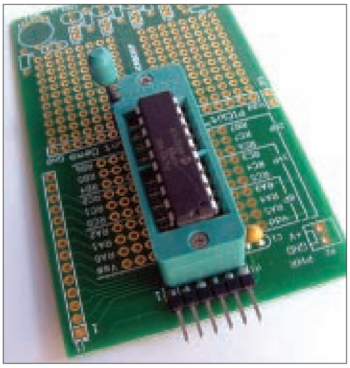
SHOW COORDINATOR
Audrey Lemieux

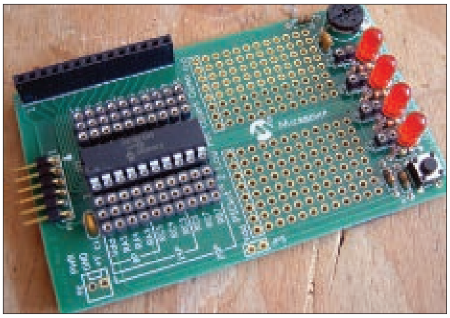
MARKETING COORDINATOR WEBSTORE
Brian Kirkpatrick
sales@nutsvolts.com

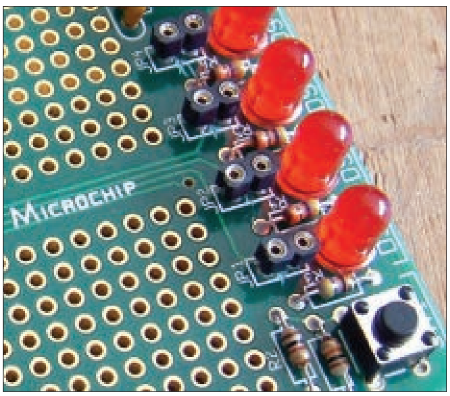
WEB CONTENT
Michael Kaudze
website@nutsvolts.com

ADMINISTRATIVE ASSISTANT
Debbie Stauffacher

PRODUCTION/GRAPHICS
Shannon Christensen







ideal for this project. They separate very easy into 10-pin to two-pin sockets. The only down side was the fact that I was limited on the wire size I could use with these sockets.

Using a 20-pin ZIF socket (Digi-Key 3M2002-ND), a 0.1 µF tantalum capacitor (+ side toward socket), and six pins of a header, 1 x 40 right angle (All Electronics, SHR-40), I was able to make a quick and easy programming board for burning multiple chips.

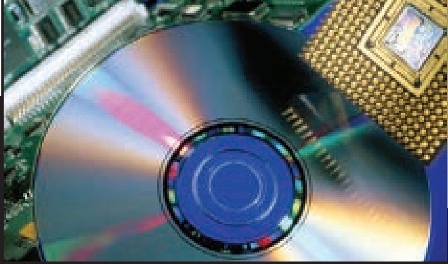
Bob Diaz
Torrance, CA

TIME FOR REMINISCING

I read with some amusement, "The End of the Wristwatch" in the July Developing Perspectives column.While I've been surrounded by technology for most of my life, I find my motivation for reading *Nuts & Volts* to be somewhat different than the Editor's perception of the average reader.

To me, most technological innovations come as a result of marketing pressures ... the need to have a new "whiz-bang" product to capture a large market share. As a result, we get half-baked products that fail to deliver on promises until several revisions, upgrades, or new models are offered. Since most everything is microprocessor

Continued on page 93



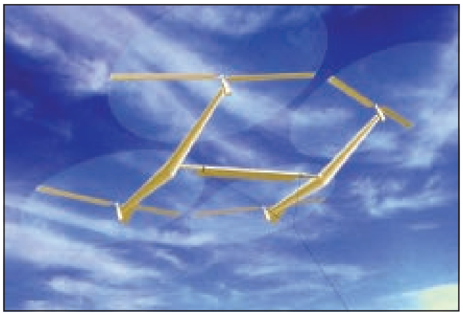
TECH KNOWLEDGEY 2009

EVENTS, ADVANCES, AND NEWS

■ BY JEFF ECKERT

ADVANCED TECHNOLOGY

ENERGY ALTERNATIVES: MILES HIGH TO DEEP UNDERGROUND



■ Artist's rendition of a flying electrical generator (by Ben Shepard).

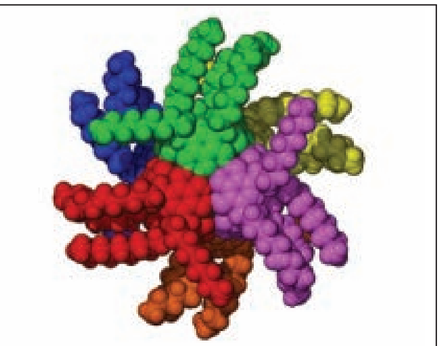


PHOTO COURTESY OF PNNL.

■ One of several MOHCs designed to improve geothermal power generation.

If you think about it, "alternative energy" makes a handy catchphrase for pundits but is so sweeping as to have little practical meaning. Take, for example, two highly divergent concepts competing for a slice of the green pie. First we have a proposed flying electric generator (FEG), rated at 240 kW and sporting four 35 ft rotors, proposed by Sky Windpower Corp. (**www.skywindpower.com**). Based on the observation that wind velocity generally increases with altitude, the company proposes to build a fleet of tethered rotorcraft that float around at 15 to 32 thousand feet, sending power back to Earth via conductive tethers. This is similar to the Laddermill concept currently under research at the Delft University of Technology (**www.tudelft.nl**), and somewhat more ambitious than things like Magenn Power's (**www.magenn.com**) MARS lighter-than-air platform, which rises to only 1,000 feet and can be paired with a diesel generator.

As interesting as the FEG idea is, it offers some nasty challenges, including how to steer aircraft around the installations and how to maintain and repair a windmill that's floating six miles above ground level. Plus, with 2006 US power generation coming in at about 4 TWh, it would take roughly a zillion of the 240 kW units to do the job.

On a more than down-to-earth level is a new heat extraction process developed by the DoE's Pacific Northwest National Laboratory (**www.pnl.gov**) that could enable more efficient geothermal power generation. The goal is to harness low temperature geothermal resources at an economical cost. PNNL scientists have developed a biphasic fluid that expands and contracts rapidly in reaction to temperature changes. In operation, the fluid is exposed to water that has been heated by underground rock, and a thermal cycling process powers a turbine generator.

The secret is a metal-organic heat carrier (MOHC) that PNNL uses in the fluid which vastly improves the thermodynamic efficiency of the heat recovery process. The big drawback is that even if it proves practical, it's estimated that it will take until 2050 for the technique to generate even 10 percent of the nation's power.

It's pretty easy to be in favor of a vague concept like alternative energy, but it's obvious that it's going to take some time to sort through the thousands of schemes and scams. And some money. A lot of money.

LASERS CREATE NEW FORMS OF METAL

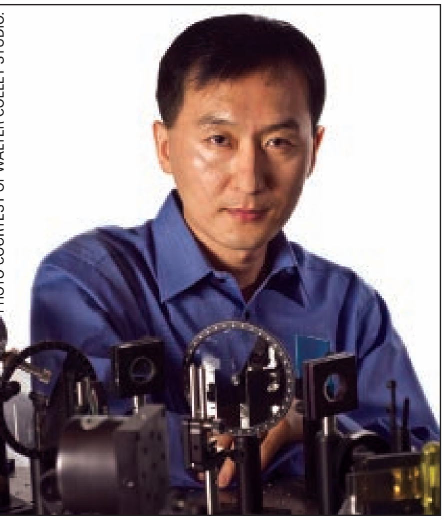


PHOTO COURTESY OF WALTER COLLEY STUDIO.

■ Dr. Chunlei Guo of the University of Rochester and his femtosecond laser.

When most of us want to blacken a piece of shiny metal, we whip out a can of Rustoleum to do the job. Ten minutes and five bucks later, voila! But Dr. Chunlei Guo and his team at the University of Rochester (**www.rochester.edu**) are doing it with bursts of light from a femtosecond laser (i.e., a laser that creates an ultra-intense beam that lasts for only a few quadrillionths of a second). This results in new forms of metal that may "guide, attract, and repel liquids and cool small electronic devices." According to Guo, "With the creation of the black metal, an entirely new class of material becomes available to us which may open up a whole new horizon for various applications."

Basically, the laser blast causes the formation of nanostructures and microstructures in the metal surfaces that alter how efficiently light can radiate from them. The structures also affect how liquid molecules react with the surfaces; the liquid spreads out over the metal because the

nanostructures attach themselves to the liquid's molecules more readily than the liquid's molecules bond to each other. In military applications, this could come in handy to — for example — cool an aircraft's electronics and heat pumps.

For what it's worth, the process can be used to change the color of almost any metal to blue, gold, or gray, as well. It does appear to cost a bit more than a can of spray paint, though. "During its brief burst," Guo noted, "the laser unleashes as much power as the entire electric grid of North America does, all focused onto a spot the size of a needle." It takes about half an hour to treat a piece of metal the size of a quarter. Maybe Dr. Guo can hook the laser up to a few flying electric generators to cut back on the electric bills.

COMPUTERS AND NETWORKING

NEW ALL-IN-ONE PC

With its market share sinking from 31.2% in Q1 2008 to 26.2% in Q1 2009, Dell, Inc. (**www.dell.com**), is trying to plug the dyke by appealing to small businesses.

■ Dell's latest all-in-one PC offers up to 79% desktop space reduction.

Enter the new Vostro All-In-One, designed to use up to 79% less desk space. As with iMacs and other cabinet-free machines, the guts and display are combined, and the Dell offering adds the availability of a VESA mount that clamps onto the edge of the desktop to further maximize usable desk area. Technologically, it's not much different from existing Dell all-in-one machines, being based on Intel Core 2 Duo processors. But it does offer optional integrated WiFi, a wireless mouse and keyboard, and a wired gigabit Ethernet connection. Maybe the best part is the price tag of $629.

SIX-CORE PROCESSORS INTRODUCED

Meanwhile, AMD (**www.amd.com**) has released three new versions of its six-core Opteron™ HE processors, aimed at 2-, 4-, and 8-P systems. According to a press release, the chips offer 18% lower platform-level power consumption, as well as 18% higher performance per watt. (Hmm. If it uses 18% less power, wouldn't it have to offer higher performance per watt even if overall performance stays the same? Oh, well. Marketing ...) In any event, the chips are already available in machines including some Hewlett-Packard ProLiant servers (up to two processors per box), Dell PowerEdge servers, and Cray's XT5m supercomputer (up to 192 processors). It was also announced that HP has integrated them into some xs9400 workstations.

NETWORKING TRASH

What if we knew exactly where our trash was going and how much energy it took to make it disappear?" asked a team of MIT researchers. "Would it make us think twice about buying bottled water or

INDUSTRY AND THE PROFESSION

ARGONNE AND BASF INK AGREEMENT

For several years, scientists at Argonne National Laboratory (**www.anl.gov**) have been developing Lithium-ion battery technology with an eye on practical electrical vehicles. A few weeks ago, it was announced that BASF (**www.basf.com**) — the world's largest chemical company — has signed an agreement to mass produce and market the Argonne-patented composite cathode materials to manufacturers of advanced Li-ion batteries. Argonne's composite cathode material employs a special combination of lithium- and manganese-rich mixed-metal oxides to extend the operating time between charges, increase the calendar life, and improve the safety of cells. In addition, enhanced material stability allows battery systems to charge at higher voltages. BASF will conduct further Lithium-ion battery material application development in its current Beachwood, OH, facility. If the company wins a DoE grant under the Recovery Act-Electric Drive Vehicle Battery and Component Manufacturing Initiative, it plans to build one of North America's largest cathode material production facilities in Elyria, OH.

DRAM INVENTOR HONORED

■ Robert H. Dennard, 2009 IEEE Medal of Honor recipient.

Robert H. Dennard, an engineer whose invention of DRAM, along with development of the MOSFET s caling theory, are among the most influential and visible developments in all of microelectronics, is being honored by IEEE with the 2009 IEEE Medal of Honor. The medal was presented on June 25 at the IEEE Honors Ceremony in Los Angeles, CA. He was granted the DRAM patent in 1968. It first began to appear in commercial use in the 1970s, at which time the largest computer memory had a capacity of only about 1 MB and required several kilowatts of power for operation.

Dennard holds more than 50 other patents and has received many previous honors, including the IEEE Cledo Brunetti Award (1982), the IEEE Edison Medal (2001), the National Medal of Technology (1988), induction into the National Inventors Hall of Fame (1997), and the Charles Stark Draper Prize by the National Academy of Engineering (2009). Apparently, he just doesn't know when to quit and still works at the IBM Watson Research Center where — at the age of 77 — he continues to investigate the limits of scaling and future evolution of microelectronics. Congrats, Bob.

■ Electronic tag for use in the Trash Track program.

'disposable' razors?"

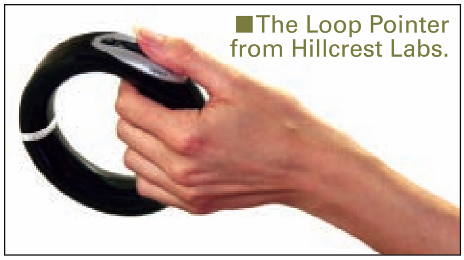
Well, probably not, but they have moved ahead with a project called Trash Track, anyway. According to Prof. Carlo Ratti, head of the MIT SENSEable City lab (**senseable.mit.edu**), "Our project aims to reveal the disposal process of our everyday objects, as well as to highlight potential inefficiencies in today's recycling and sanitation systems. The project could be considered the urban equivalent of nuclear medicine — when a tracer is injected and followed through the human body."

The Trash Track program involves enlisting volunteers in two cities (New York and Seattle) who will allow chunks of their trash to be tagged with special wireless locators. Thousands of the devices will be attached to representative samples of garbage, from which they will continuously determine their location via triangulation, allowing real-time processing of received data. From a website, the public will be able to view the migration patterns of their refuse. In addition, gathered information is scheduled to go on display this month in New York and Seattle libraries. I leave it to the reader to evaluate the merit of the program, but one question seems obvious. Who is going to collect and remove the thousands of battery-powered transmitters from the environment when this is over?

CIRCUITS AND DEVICES

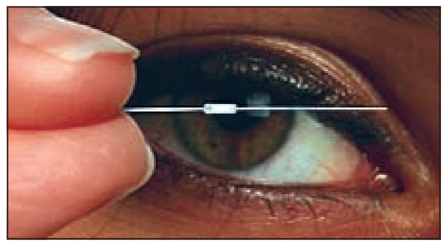
WIRELESS POINTER FOR PC-TO-TV

According to a recent Consumer Electronics Association (CEA) report, in excess of seven million US households now have a personal computer connected to a television set for Web browsing and viewing media content. If you are among them, you might be interested in Hillcrest Labs' (**www.hillcrestlabs.com**) Loop Pointer, which is basically a Freespace® mouse that lets you control an on-screen cursor from distances of up to 30 ft (9 m). You simply hook it to your PC or Mac via a small USB 2.0 transceiver (included) and away you go. It is applicable to a variety of functions, including mouse for TV, PowerPoint, and other presentations, and as an alternative controller for the KODAK Theatre HD Player. Because it uses RF rather than infrared communications, there is no line-of-sight requirement for its operation. The device lists for $99 and is available through Hillcrest or **Amazon.com**.



■ The Loop Pointer from Hillcrest Labs.

WORLD'S SMALLEST REED SWITCH



■ The GR150 reed switch from Standex.

From across the pond comes the GR150 from Standex Electronics, billed as the world's smallest reed switch. It is geared for applications in which the available magnetic field is extremely low and/or space limitations weigh heavily in product design, including hearing aids and other medical devices, handhelds, cell phones, etc. The device cross-sectional dimensions are only 0.8 by 1.2 mm, with a glass length of 3.7 mm. Overall length, including the leads, is 35.0 mm. The GR150 is rated at 1W and can switch 30V/0.05A maximum with a break-down voltage of 100V. Sensitivity ranges from three to 20 A turns with an operating temperature range of -40 to + 125°C. For more details, visit **www.standexelectronics.com**. **NV**

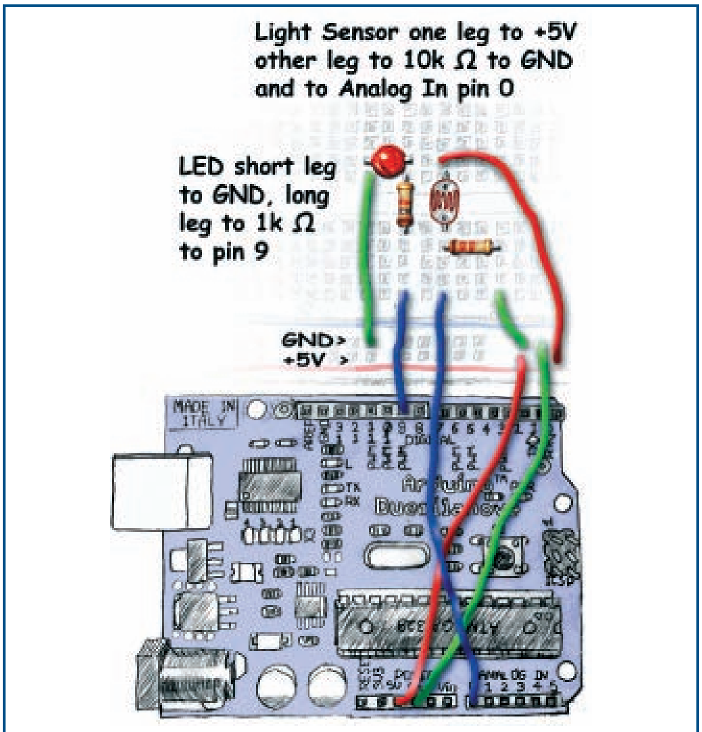
#14 SMILEY'S WORKSHOP

AVR MICROCONTROLLER: C PROGRAMMING - HARDWARE - PROJECTS

Some ALP Sensors

Follow along with this series! Joe's book & kits are available in our webstore at **www.nutsvolts.com**

by Joe Pardue



■ FIGURE 1. CdS light sensor layout.

Recap

In recent Workshops, we've been using a new development board and components kit: the Arduino Duemilanove and the Arduino Projects Kit (available from *Nuts & Volts* and Smiley Micros). We recognized that The Arduino Way (TAW) is a very simple and easy way to begin using microcontrollers. And we learned, that while TAW uses a C-like language, it does not (IMHO) provide a clear path to learning the C or AVR architecture — both of which are our long-term goals for this Workshop series. So, we were introduced to A C Way (ACW) that uses more standard (again IMHO) AVR tools. We decided to discuss projects using the kit in TAW, but also provided the software ACW in the Workshop zip file for those ready to move on. After we've introduced all the kit parts, we will then move exclusively to ACW since we will be looking at issues that are more difficult to accomplish TAW (such as using timer interrupts).

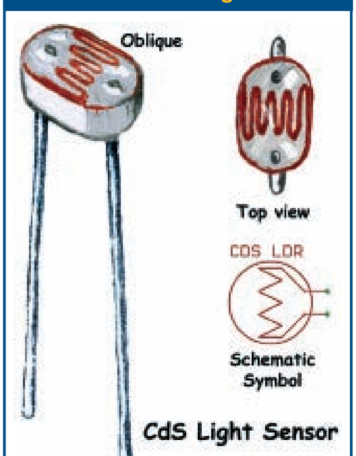
Last month, we learned how to build a command interpreter and how to make beautiful music (okay, noise) on a piezo element. This month, we are going to look at components from the kit that sense light and temperature.

Light Sensor

Cadmium Sulfide (CdS) has the interesting property that its resistance drops proportional to the amount of light falling on it. **Figure 2** shows the sensor in the Arduino Projects Kit. I'm not going to try to explain how this works since Einstein got a Nobel Prize for explaining it and apparently even he wasn't completely correct. In the dark, the resistance is about 138K ohms that drops to about 23K ohms under my work lights. What you get will, of course, vary depending on your lights. Theoretically, you could use this to make a sensor that outputs some physical measure of light such as lumens, but the process of calibrating such a sensor to a standard brightness is far more complex than we want to get into at the moment. So, we will simply use our sensor to recognize changes in light in our specific environment and use those changes to modify the blink rate of an LED as an indicator of relative brightness.

The source for this code is nearly identical to the AnalogInput example in the Arduino IDE and the code ported from TAW to ACW in Workshop 12 (you can get that code from the workshop12.zip file available at **www.nutsvolts.com**). Try not to get confused between the AnalogInput example and the code used for the

■ FIGURE 2. CdS light sensor.



layout in **Figure 1**. In the code, the ledPin should be changed to pin 9 and the sensor pin to Analog In 0. And no, I didn't move these pins around to confuse you. I did it to confuse myself. (Sorry about that.) It does show how easy it is to change the pins in either the code or the layouts just as long as you keep them consistent.

Light Sensor Components, Schematic, Layout

You can follow the schematic in **Figure 3** and the layout in Figure 1 to build this light sensor project hardware. Then, modify the Arduino example for Analog Input to conform to the actual pinout.

A Word or Two about Storing and Showing Sensor Data

We used the cop-out with the light sensor that calibrating the data to some physical reference was beyond what we want to do here (and 'we' didn't even ask for your opinion!), so we let an LED blink at a rate proportional to the sensor output from the lights in my personal workshop. We can assume that your workshop will be more or less lighted the same and that you can adjust the code if you live in a cave or on a beach. But what if we wanted to calibrate the sensor to some actual physical measure of light that contains — as real physics often does — some fractional data?

There are many situations where we don't really care if anybody ever sees any indication of a sensor output (like the O_2 sensor in our car) since the value is being used inside an embedded system that percolates along without our help. Sometimes — such as when we are sensing room temperature — we want the sensor output to have some meaning to us.

Our next project uses the LM35 temperature sensor from the Arduino Projects Kit and outputs 10 mV per degree Centigrade accurate to 0.5 °C, and while that is a fun fact, we'd hardly know that the room was too darn hot based on a reading of 0.375 volts (never mind our flop-sweat as a trust-worthy sensor). We want to see that it is 99.5°F [37.5 °C for the rest of the world who can translate the output mV to °C in their head if they wanted to, but I think Fahrenheit, so 99.5 is hot and 37.5 is cold]. Anyway, the point is that we want to see something meaningful to us.

A Quick Introduction to Signed Decimal Numbers

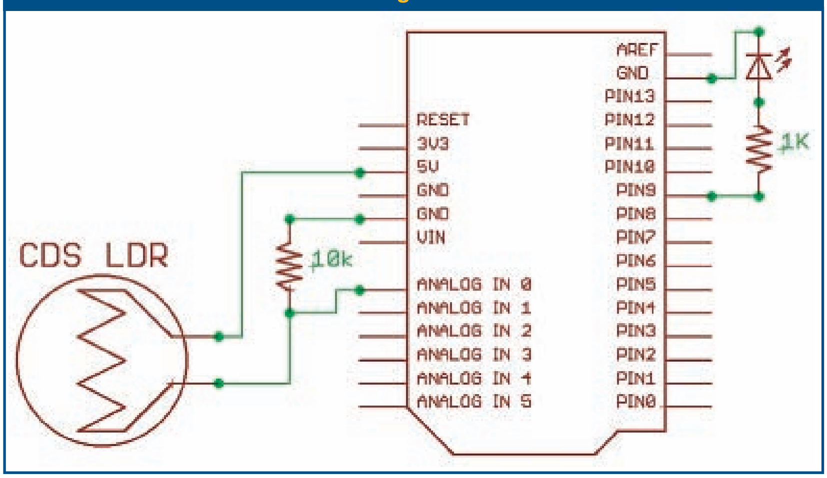
This brings us to an issue with computers. Computers use integers (whole numbers {0,1,2,3,...}) to manipulate data, but we want to see temperatures with decimal fractions; 98 won't cut it, but 98.6 is a good healthy number. Also, the LM35 is accurate to 0.5°C so why waste good fractional information? In our specific case, we use an ADC to measure a value expressed as a whole number between 0 and 1023, but we will be showing a temperature such as 98.6°F, with an integer part (98), a decimal point (.), and a decimal part (6). To further complicate things, our temperature scales also use negative numbers (like the temperature at which nitrogen liquefies: -346°F).

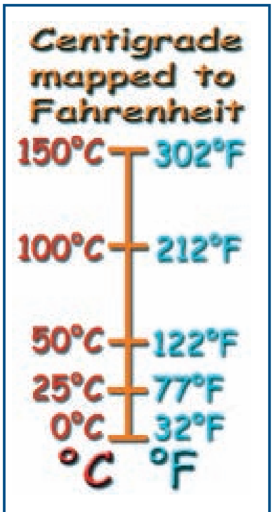
Computers store data as whole numbers and they either have special hardware or software to manipulate this basic whole number data type as other data types (such as negative or decimal numbers). They pretend to work with decimal numbers by storing the integer part and the decimal part as separate whole numbers. They can be told to consider a number as signed (can hold positive + and negative -) by looking at the most significant bit of the data. [A byte holds 0 to 255, a signed byte 'holds' -128 to +127 where the highest bit represents the sign.] All this is by way of introduction, since going into the details can get complex quick. We will look at a technique for keeping our data in the original ADC-generated whole numbers (10-bits or 0 to 1023) while presenting that data to people in a human comprehensible format such as a signed decimal number.

Showing Integer Data As Signed Decimal Fractions

Our focus in this article is TAW, but to help with some concepts, we need to spend a few moments ACW. The C programming language has a lot of tools that help the user convert between data types. We could load our ADC data into double or floating-point data types; do the math that converts the ADC reading to 'myTemp = 98.6;' and then print it with: printf("Temperature = %f",myTemp). We could, that is, if we want to drag along a couple of extra kilobytes of code to process floating-point data. That is a lot of code space (expensive in microcontrollers) for a little convenience, so the avr-libc uses several versions of 'printf' that compile to less functional but much smaller versions for folks who aren't interested in the extra data conversion features. The avr-libc default version when you

■ FIGURE 3. CdS light sensor schematic.





■ FIGURE 4. Centigrade mapped to Fahrenheit.

use printf("Temperature = %f",myTemp) will output: "Temperature = ?" since it — by default — doesn't do floating-point. This causes no end of confusion to novices who learn C from K&R but then don't read the avr-libc manual. [Too frequent AVRFreaks question: "Plz hlp me!!!!!!! I gt a '?' whn I uz printf, why zat?" Too frequent answer: "RTFM and learn to type!"] You can read all about this in the avr-libc manual, but I recommend just forgetting about using and printing real floating-point data for the time being and use the method we'll discuss in this section which works equally well for TAW and ACW.

Let's say we want to print the normal human body temperature in Fahrenheit, which requires a decimal fraction: 98.6°F. The first trick we use is to keep our body temperature data stored in integers that are ten times the real value. We thus store 986 rather than 98.6. The second trick is to recover the real value for the integer and decimal fraction parts only when we want to show the data to people. The final trick is to print these two values separately with a decimal point printed between them. We show the text 98.6 by separately printing the '98' then a decimal point '.', and then the fractional part '6'. We will use the C '/' division and '%' modulo operators to get the integer and fractional parts of the number.

The '/' division operator in C yields only the integer part of the division so in C, 986/10 = 98. The '%' modulo operator yields only the remainder part of a division so in C, 986%10 = 6. We can use these operators as follows:

```
// show 986 as 98.6
whole = 986/10;         // divide to get the
                        // integer
decimal = 986%10;      // modulo to get the
                        // fraction
printf("986/10 = %d.%d", whole,decimal);
```

And the results output to the terminal would be:

```
986/10 = 98.6
```

This technique will also come in handy with TAW since the Serial.println() function throws away the fractional part of a floating-point value so you will have to determine both the whole and decimal parts, and print them with two separate calls to the Serial.Print function as we will see in a minute.

Converting Centigrade to Fahrenheit

Let's take a moment to look at another issue related to presenting the data specific to temperature. We are storing raw integers from the ADC that map directly to Centigrade values (we'll look at the electrical and microcontroller details in a minute). And, while I have nothing against °C, I am at the moment sweating to °F, as are many of the readers of this Workshop. We can use the standard conversion formula:

Fahrenheit = ((9*Centigrade)/5) + 32

This formula maps the data as shown in **Figure 4**. Be sure and look at the showTemp() function shown in the 'LM35_Temperature Source Code' below since I also round off the data to 0.5 to conform to the sensor accuracy.

LM35_Temperature Source Code

The full source code in TAW and ACW for this project is available in Workshop14.zip.

```
// LM35_Temperature TAW
// Joe Pardue June 4, 2009

// variable to hold the analog input value
int analogValue = 0;

// variables used to fake the decimal value
int whole = 0;
int decimal = 0;

// For the Arduino using 5V, the ADC measures
// 4.9 mV per unit use 49 to avoid floats
#define ADCUnit 49

void showTemp(int ADCin);

void setup()
{
 // begin the serial communication
 Serial.begin(9600);
}

void loop()
{
 // read the voltage on Analog Pin 0
 analogValue = analogRead(0);

 // show the reading with faked decimals
 showTemp(analogValue);

 // delay 1 second before the next reading:
 delay(1000);
}

void showTemp(int ADCValue)
{
 // print ADC value
 Serial.print("1.06 TAW LM35 - raw ADC: ");
 Serial.print(ADCValue, DEC);

 // make Centigrade
 whole = (ADCValue * ADCUnit)/100;
 decimal = (ADCValue * ADCUnit)%100;

 // round to '0.5'
```

```
    if(decimal > 50){ decimal = 0; whole +=1;}
    else decimal = 5;

    // print degrees Centigrade
    Serial.print(" > degree C: ");
    Serial.print(whole, DEC);
    Serial.print('.');
    Serial.print(decimal, DEC);

    // convert Centigrade to Fahrenheit
    whole = ((9*(ADCValue * ADCUnit))/5)/100;
    decimal = ((9*(ADCValue * ADCUnit))/5)%100;

    // round to '0.5'
    if(decimal > 50){ decimal = 0; whole +=1;}
    else decimal = 5;

    // print in degrees Fahrenheit
    Serial.print(" > degree F: ");
    whole += 32; // scale it to °F
    Serial.print(whole, DEC);
    Serial.print('.');
    Serial.println(decimal, DEC);
  }
```

The output of this code in the Arduino IDE serial monitor is shown in **Figure 5**.

The LM35 Temperature Sensor

Now that we've looked at some ideas about how to present integer data with a faked decimal point, let's look at how to get that data.

The LM35 temperature sensor outputs voltage that is linearly proportional to the temperature in degrees Celsius (Centigrade). The LM35 datasheet says: "0.5°C accuracy guaranteeable at 25°C" and since it outputs 10 mV per °C (5 mV per 0.5°C), if we can measure the voltage with an accuracy of 5 mV we will match the LM35 accuracy.

Our 10-bit ADC will map an input voltage from zero to five volts to integers from 0 to 1023. The resolution is 5V/1024 ADCunits = .0049V/ADCunit (.0049V is 4.9 mV). The LM35 accurately outputs 5 mV per °C and the ADC measures 4.9 mV per ADCunit, so our AVR ADC is well matched with the LM35 for accuracy.

■ FIGURE 6. Temperature, voltage, and ADC ranges.

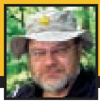
```
9600 baud
1.06 TAW LM35 - raw ADC: 38 > degree C: 19.0 > degree F: 66.0
1.06 TAW LM35 - raw ADC: 39 > degree C: 19.5 > degree F: 66.5
1.06 TAW LM35 - raw ADC: 39 > degree C: 19.5 > degree F: 66.5
1.06 TAW LM35 - raw ADC: 42 > degree C: 21.0 > degree F: 69.5
1.06 TAW LM35 - raw ADC: 45 > degree C: 22.5 > degree F: 72.0
1.06 TAW LM35 - raw ADC: 48 > degree C: 24.0 > degree F: 74.5
1.06 TAW LM35 - raw ADC: 49 > degree C: 24.5 > degree F: 75.5
1.06 TAW LM35 - raw ADC: 51 > degree C: 25.0 > degree F: 77.0
1.06 TAW LM35 - raw ADC: 51 > degree C: 25.0 > degree F: 77.0
1.06 TAW LM35 - raw ADC: 52 > degree C: 25.5 > degree F: 78.0
1.06 TAW LM35 - raw ADC: 51 > degree C: 25.0 > degree F: 77.0
1.06 TAW LM35 - raw ADC: 50 > degree C: 24.5 > degree F: 76.5
1.06 TAW LM35 - raw ADC: 50 > degree C: 24.5 > degree F: 76.5
1.06 TAW LM35 - raw ADC: 49 > degree C: 24.5 > degree F: 75.5
1.06 TAW LM35 - raw ADC: 48 > degree C: 24.0 > degree F: 74.5
```

As we've discussed above, we don't want to mess with decimal fractions. So, first we note that 4.9 mV is .0049 volts so we will multiply our per ADC unit by 10,000, giving us the whole number 49 for each ADC unit. This is the value we will store [thus the ADCUnit used in the source code]. For example, if the ADC reads 204 (out of a maximum of 1023), we multiple 49*204 = 9996, which is the integer that we store. We will only extract the decimal

```
void showTemp(int ADCValue)
{
  // print ADC value
  Serial.print("1.06 TAW LM35 - raw ADC: ");
  Serial.print(ADCValue, DEC);

  // make Centigrade
  whole = (ADCValue * ADCUnit)/100;
  decimal = (ADCValue * ADCUnit)%100;

  // round to '0.5'
  if(decimal > 50){ decimal = 0; whole +=1;}
  else decimal = 5;

  // print degrees Centigrade
  Serial.print(" > degree C: ");
  Serial.print(whole, DEC);
  Serial.print('.');
  Serial.print(decimal, DEC);

  // convert Centigrade to Fahrenheit
  whole = ((9*(ADCValue * ADCUnit))/5)/100;
  decimal = ((9*(ADCValue * ADCUnit))/5)%100;

  // round to '0.5'
  if(decimal > 50){ decimal = 0; whole +=1;}
  else decimal = 5;

  // print in degrees Fahrenheit
  Serial.print(" > degree F: ");
  whole += 32; // scale it to °F
  Serial.print(whole, DEC);
  Serial.print('.');
  Serial.println(decimal, DEC);
}
```

■ FIGURE 5. Output in Arduino Serial Monitor.

You can find the source code and supplements for this article in Workshop13.zip on the *Nuts & Volts* and Smiley Micros websites.



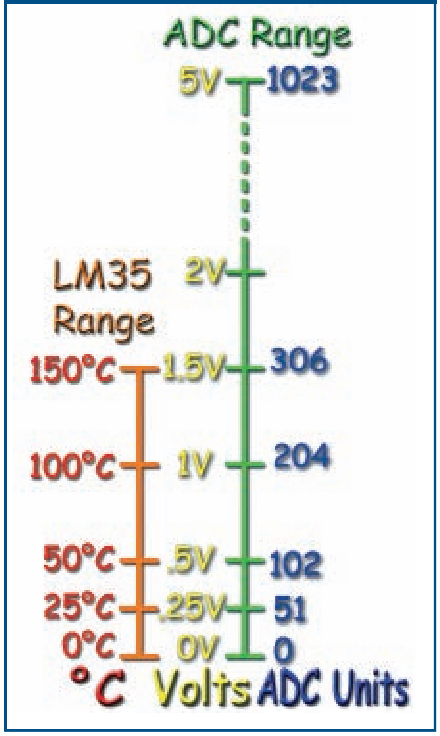
temperature when we want to show it. In this case, the actual temperature is 100°C or 212°F as shown in **Figure 6**.

Temperature Sensor Components, Schematic, Layout

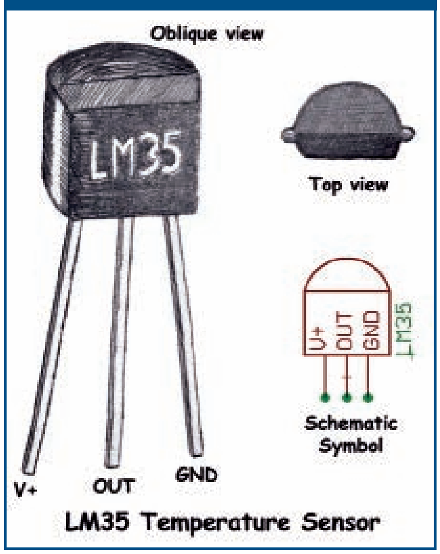
The hardware construction is fairly simple for this project. **Figure 7** shows the device we will be using. **Figure 8** shows how we will hook it up using just three wires for +5V, GND, and Analog Pin 0 as shown in **Figure 9**.

Once you get this working, you can do a quick experiment to demonstrate the lag in the measured temperature and the external temperature. It takes a few seconds for the external temperature to move from the surface of the LM35 to the sensor. You can see this by observing the room temperature output, then lightly squeezing the LM35 between your thumb and index finger. As shown in Figure 5, it takes a couple of seconds to begin to respond; once you remove your fingers, it takes several seconds — depending on how long you held it — for it to get back to room temperature. In my case, it took a minute or so to

■ FIGURE 7. LM35 temperature sensor.



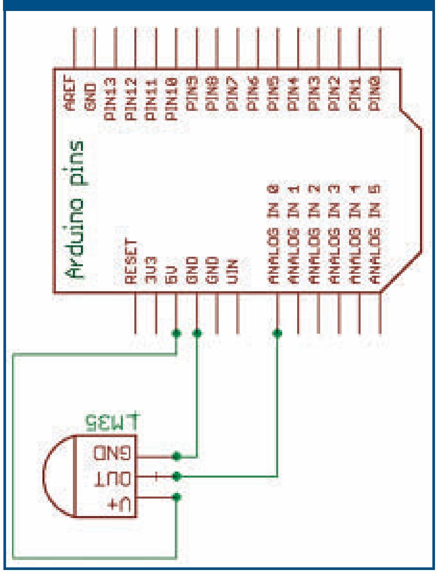
■ FIGURE 8. Temperature sensor schematic.



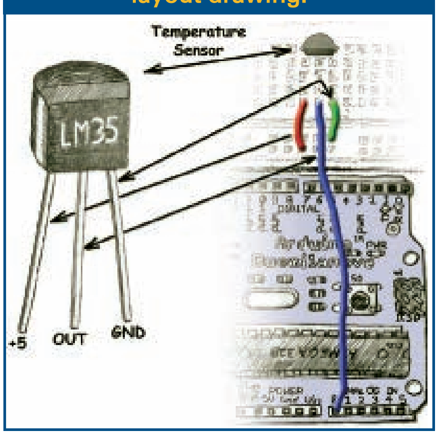
go from the frigid 66.0°F (in the local bookstore where I tested it over a cup of too expensive tea) to a maximum of 85.0°F. I don't think this low temperature indicates anything about my zombihood, since the 98.6°F would require sticking the LM35 into a convenient orifice — something I'm not willing to do in public. (The lady at the next table was giving me strange looks, possibly because of my laptop/ALP setup and possibly because I was laughing out loud).

Okay, too much fun for one month. Next month we'll look at infrared object detection using the QRD1114 from the Arduino Projects Kits part, and we'll learn what bunnies and snakes have to do with counting tomato soup cans. **NV**

■ FIGURE 9. Temperature sensor schematic.



■ FIGURE 10. Temperture sensor layout drawing.

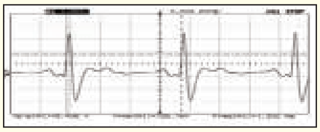


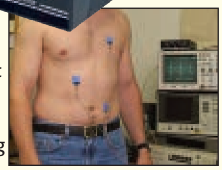
Back To School Time!

Providing Fun Electronics Learning Kits For Decades

Electrocardiogram ECG Heart Monitor

- ✔ **Visible and audible display of your heart rhythm!**
- ✔ **Bright LED "Beat" indicator for easy viewing!**
- ✔ **Re-usable hospital grade sensors included!**
- ✔ **Monitor output for professional scope display**
- ✔ **Simple and safe 9V battery operation**





Today, we all try to be "Heart Smart". And that usually means a healthy diet, exercise, preventive maintenance, and the knowledge of what to do... "if". Beyond that, unless you're a cardiologist, the workings of your heart are probably a mystery. Not anymore!

Use the ECG1C to astound your physician with your knowledge of ECG/EKG systems. Enjoy learning about the inner workings of the heart while, at the same time, covering the stage-by-stage electronic circuit theory used in the kit to monitor it. The three probe wire pick-ups allow for easy application and experimentation without the cumbersome harness normally associated with ECG monitors. The documentation with the ECG1C covers everything from the circuit description of the kit to the circuit description of the heart!

Multiple "beat" indicators include a bright front panel LED that flashes with the actions of the heart along with an adjustable level audio speaker output that supports both mono and stereo hook-ups. In addition a monitor output is provided to connect to any standard oscilloscope to view the traditional style ECG/EKG waveforms just like you see on TV... or in the ER! See the display above? That's one of our engineers, hooked up to the ECG1C after an engineering meeting!

The fully adjustable gain control on the front panel allows the user to custom tune the differential signal picked up by the probes giving you a perfect reading and display every time! 10 hospital grade re-usable probe patches are included together with the matching custom case set shown. Additional patches are available in 10-packs. Operates on a standard 9VDC battery (not included) for safe and simple operation. Note, while the ECG1C professionally monitors and displays your heart rhythms and functions, it is intended for hobbyist usage only. If you experience any cardiac symptoms, seek proper medical help immediately!

ECG1C	**Electrocardiogram Heart Monitor Kit With Case & Patches**	**$44.95**
ECG1WT	**Electrocardiogram Heart Monitor, Factory Assembled & Tested**	**$89.95**
ECGP10	**Electrocardiogram Re-Usable Probe Patches, 10-Pack**	**$7.95**

42 Watt Universal Stereo Amplifier System

iPod Touch & Pink Floyd CD Not Included Those Are Mine!

- ✔ **42 watt class D amplifer, spread spectrum design!**
- ✔ **87% efficient heat-free operation!**
- ✔ **0.1% distortion for clean crisp audio response!**
- ✔ **Balanced and unbalanced audio inputs!**
- ✔ **All DC controls for noise free operation!**
- ✔ **Selectable pre/post process line outputs**
- ✔ **Short-circuit proof!**
- ✔ **Operates on 12-18VDC at a mere 3.3A!**
- ✔ **Compact and attractive shielded aluminum case!**

The success of the tiny little UAM4 stereo amplifier was incredible, but there were a lot of requests for a complete system built around its technology. These requests seemed like a great idea, so here it is, the UAM4SYS!

The amplifer is based on a single SMT device that runs in class D, which means it's highly efficient and produces very little heat! Your power goes into the audio output, not heat on a heatsink! The results, 21 watts per channel of stereo or 42 watts total or mono audio power! All cool running without the need for heatsinks or ventilation requirements! Easy-to-use board jumpers offer selectable gain of +22dB, +25dB, +29.5dB or +36dB to match your input levels. Board jumpers also enable protection and shutdown options as well as stereo/mono/bridge mode.

The amplifier also features built-in click and pop suppression to protect not only your ears and sanity, but your speakers and equipment! Line outputs are selectable pre or post processing and the headphone circuit gives you 64 steps of audio level and stores your last setting! Construction is through-hole for easy assembly, other than the SMT devices which are pre-installed. Runs on 28VDC for full rated output but runs well on 12VD for mobile applications! Visit www.ramseykits.com for complete details, specs., and accessories.

UAM4SYS	**42 Watt Stereo Ammplifier Kit With Case**	**$169.95**

Tri-Field Meter & "Ghost Detector"

- ✔ **See electric, magnetic, and RF fields!**
- ✔ **Watch the magnetic fields of the earth!**
- ✔ **Sense different magnetic poles**
- ✔ **Detect RF transmitter fields**
- ✔ **Graphical LED "sees" the invisible fields**

As Seen On CBS's Ghost Whisperer

The TFM3C has three separate field sensors that are user selectable to provide a really cool readout on two highly graphical LED bargraphs! Utilizing the latest technology, including Hall Effect sensors, you can walk around your house and actually "SEE" these fields around you! You will be amazed at what you see. How sensitive is it? Well, you can see the magnetic field of the earth... THAT'S sensitive!

The technical applications are endless. Use it to detect radiation from monitors and TV's, electrical discharges from appliances, RF emissions from unknown or hidden transmitters and RF sources, and a whole lot more! If you're wondering whether your wireless project or even your cell phone is working, you can easily check for RF! A 3-position switch in the center allows you to select electric, magnetic, or RF fields. A front panel "zero adjust" allows you to set the sensors and displays to a known clean "starting point".

If the TFM3C looks familiar, it's probably because you saw it in use on the CBS show Ghost Whisperer! It was used throughout one episode (#78, 02-27-2009) to detect the presence of ghosts! In the electric mode, the TFM3C's displays will wander away from zero even though there isn't a clear reason for it What it was in the Ghost Whisperer was a friendly ghost. What it will be in your house... who knows! Runs on 4 AAA batteries.

TFM3C	**Tri-Field Meter Kit With Case**	**$74.95**

High-Tech School Favorites!

FM Stereo Transmitter

- ✔ **Rock stable PLL synthesized exciter**
- ✔ **Front panel digital control and display of all parameters!**
- ✔ **Professional metal case**
- ✔ **Super audio quality!**
- ✔ **25mW kit and 1W export models!**

For nearly a decade we've been the leader in hobbyist FM radio transmitters. When it became time for a new model, we started from the ground up! We told our engineers we wanted a new technology transmitter that would provide FM100 series quality without the advanced mixer features. They took it as a challenge and designed not one, but TWO transmitters!

The FM30 is designed using through-hole technology and components and is available only as a do-it-yourself kit, with a 25mW output very similar to our FM25 series. Then the engineers redesigned their brand-new design using surface mount technology (SMT) for a very special factory assembled and tested FM35WT version, with 1W output for our export-only market! Both are designed around an RF tight vinyl clad metal enclosure for noise free and interference free operation. All settings are done through the front panel digital control and LCD display! All settings are stored in non-volatile memory for future use.

Both the FM30 and FM35WT operate on 13.8 to 16VDC and include a 15VDC 110/220VAC plug in power supply. The stylish black anodized aluminum case measures 5.55"W x 6.45"D x 1.5"H. and is a great match to your other equipment. *(Note: After assembly of this do-it-yourself hobby kit, the user is responsible for complying with all FCC rules & regulations within the US, or any regulations of their respective governing body. FM35BWT is for export use and can only be shipped to locations outside the continental US or valid APO/FPO addresses or valid customs brokers for end delivery outside the continental US.)*

FM30B	**FM Stereo Transmitter Kit**	**$199.95**
FM35BWT	**1W Export Only Version**	**$299.95**

Electronic Learning Labs

- ✔ **Learn and build!**
- ✔ **130, 200, 300, & 500 in one!**
- ✔ **Super comprehensive training manuals!**

Whether you want to learn the basics of electricity, the theory of electronics, or advanced digital technology, our lab kits are for you! Starting with our PL130, we give you 130 different electronic projects, together with a comprehensive 162 page learning manual. A great start for the kids...young and old! Next, check out the PL200, that gives you 200 very creative and fun projects, and includes a neat interactive front panel with 2 controls, speaker, LED display and a meter.

From there, step up to our PL300, which gives you 300 separate electronic projects along with 165 page learning and theory manual. The PL300 walks you through the learning phase of digital electronics.

If you're looking for the ultimate lab kit, check out our PL500. Includes a whopping 500 separate projects, a 152 page starter course manual, a 78 page advanced course manual, and a 140 page programming course manual! The PL500 covers everything from the basics to digital programming! Learn all about electronics theory, and digital technology the fun way and build some neat projects!

PL130	**130-In-One Lab Kit**	**$47.95**
PL200	**200-In-One Lab Kit**	**$62.95**
PL300	**300-In-One Lab Kit**	**$84.95**
PL500	**500-In-One Lab Kit**	**$199.95**

OBDII *CarChip Pro*

The incredible OBDII plug-in monitor that has everyone talking! Once plugged into your vehicle it monitors up to 300 hours of trip data, from speed, braking, acceleration, RPM and a whole lot more. Reads and resets your check engine light, and more!

8226 CarChip Pro OBDII Monitor $99.95

Practice Guitar Amp & DI

Practice your guitar without driving your family or neighbors nuts! Works with any electric, acoustic-electric, or bass guitar. Plug your MP3 player into the aux input and practice to your favorite music! Drives standard headphones and also works as a great DI!

PGA1 Personal Practice Guitar Amp Kit $64.95

Passive Aircraft Monitor

The hit of the decade! Our patented receiver hears the entire aircraft band without any tuning! Passive design has no LO, therefore can be used on board aircraft! Perfect for airshows, hears the active traffic as it happens! Available kit or factory assembled.

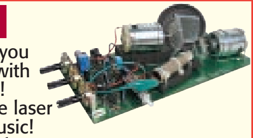
ABM1 Passive Aircraft Rcvr Kit $89.95

LED Blinky

Our #1 Mini-Kit for over 35 years! Alternately flashes two jumbo red LED's. Great for signs, name badges, model railroading, and more. Used throughout the world as the first learning kit for students young and old! Great solder practice kit. Runs on 3-15 VDC.

BL1 LED Blinky Kit $7.95

Laser Light Show



Just like the big concerts, you can impress your friends with your own laser light show! Audio input modulates the laser display to your favorite music! Adjustable pattern & speed. Runs on 6-12VDC.

LLS1 Laser Light Show Kit $49.95

Electronic Siren

Exactly duplicates the upward and downward wail of a police siren. Switch closure produces upward wail, releasing it makes it return downward. Produces a loud 5W output, and will drive any speaker! Horn speakers sound the best! Runs on 6-12VDC.

SM3 Electronic Siren Kit $7.95

Universal Timer

Build a time delay, keep something on for a preset time, provide clock pulses or provide an audio tone, all using the versatile 555 timer chip! Comes with circuit theory and a lots of application ideas and schematics to help you learn the 555 timer. 5-15VDC.

UT5 Universal Timer Kit $9.95

Voice Activated Switch

Voice activated (VOX) provides a switched output when it hears a sound. Great for a hands free PTT switch or to turn on a recorder or light! Directly switches relays or low voltage loads up to 100mA. Runs on 6-12 VDC.

VS1 Voice Switch Kit $9.95

Tone Encoder/Decoder

Encodes OR decodes any tone 40 Hz to 5KHz! Add a small cap and it will go as low as 10 Hz! Tunable with a precision 20 turn pot. Great for sub-audible "CTS" tone squelch encoders or decoders. Drives any low voltage load up to 100mA. Runs on 5-12 VDC.

TD1 Encoder/Decoder Kit $9.95

20 Watt Mini Audio Amp

Delivers a super clean 20W output from one SMT package! Ultra efficient class D design produces no heat. PCB can be snapped into a small circle for special applications. Runs on 18VDC for rated output, or down to 10VDC for reduced output.

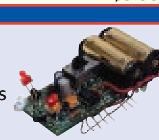
UAM2 20W Subminiature Amp Kit $34.95

Touch Switch

Touch on, touch off, or momentary touch hold, it's your choice with this little kit! Uses CMOS technology. Actually includes TWO totally separate touch circuits on the board! Drives any low voltage load up to 100mA. Runs on 6-12 VDC.

TS1 Touch Switch Kit $9.95

Walking Electronic Bug



Built around a pair of subminiature cell phone motors, this bug wanders around looking for things to bump into! Sensors below his LED eyes sense proximity and make him turn away! Steer him with flashlights too! Runs on two "N" batteries.

WEB1 Walking Bug Kit $29.95

Mad Blaster Warble Alarm

If you need to simply get attention, the "Mad Blaster" is the answer, producing a LOUD ear shattering raucous racket! Super for car and home alarms as well. Drives any speaker. Runs on 9-12VDC.

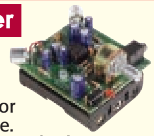
MB1 Mad Blaster Warble Alarm Kit $9.95

Xenon Tube Strobe Light

Create amazing effects with an authentic Xenon tube strobe light! Creates a super bright white FLASH with a variable speed of 2 to 20 flashes second. Just connect 110VAC and and you have a complete strobe light!

K5300 Xenon Tube Strobe Light Kit $19.95

Stereo Ear Super Amplifier



Ultra high gain amp boosts audio 50 times and it does it in stereo with its dual directional stereo microphones! Just plug in your standard earphone or headset and point towards the source. Incredible gain and perfect stereo separation!

MK136 Stereo Ear Amp Kit $9.95

Water Sensor Alarm

This little $8 kit can really "bail you out"! Simply mount the alarm where you want to detect water level problems (sump pump!). When the water touches the contacts the alarm goes off! Sensor can even be remotely located. Runs on a standard 9V battery.

MK108 Water Sensor Alarm Kit $6.95

Air Blasting Ion Generator

Generates negative ions along with a hefty blast of fresh air, all without any noise! The steady state DC voltage generates 7.5kV DC negative at 400uA, and that's LOTS of ions! Includes 7 wind tubes for max air! Runs on 12-15VDC.

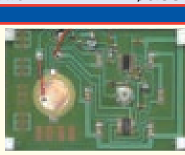
IG7 Ion Generator Kit $64.95

HV Plasma Generator

Generate 2" sparks to a handheld screwdriver! Light fluorescent tubes without wires! This plasma generator creates up to 25kV at 20kHz from a solid state circuit! Build plasma bulbs from regular bulbs and more! Runs on 16VAC or 5-24VDC.

PG13 HV Plasma Generator Kit $64.95

SMT Soldering Lab



Learn all about SMT parts and how to solder them! Surface mount parts are tiny and require a special skill to solder. This lab and course covers it all, and you end up with a great "Decision Maker" kit when done!

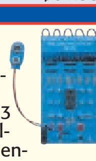
SM200K SMT Soldering Lab Kit $22.95

Soldering Lab

The perfect beginner's project specifically designed to teach you the fundamentals of soldering and PC boards. You will not only learn soldering, but hoto troubleshoot soldering problems and how to fix them! Final project runs on 9V battery.

SP1A Soldering Lab Kit $9.95

Soldering Parts Lab



Not only will you learn soldering and desoldering but you will also learn component identification and color codes! Includes 163 solder points, and you will learn how to solder all types of components. The comprehensive manual even includes exams!

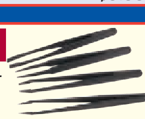
SP3B Soldering Parts Lab Kit $9.95

IC AM/FM Radio Lab

Learn all about AM/FM radio theory, IC theory, and end up with a high quality radio! Extensive step-by-step instructions guide you through theory, parts descriptions, and the hows and whys of IC design. Runs on a standard 9V battery.

AMFM108K AM/FM IC Radio Lab Kit $34.95

Non-Conductive Tweezers



We've discussed tweezers and magnifiers while working with SMT components. Working with highly sensitive components, ESD safe tweezers can be a life saver! This set of 4 non-conductive tweezers are perfect for any static sensitive devices, and are priced right!

VTTWSET2 Non-Conductive Tweezers Set $3.95

3-In-1 Multifunction Lab

The handiest item for your bench! Includes a RoHS compliant temp controlled soldering station, digital multimeter, and a regulated lab power supply! All in one small unit for your bench! It can't be beat!

LAB1U 3-In1 Multifunction Solder Lab $129.95

Just Off The Press!

Get the new 2009 Ramsey Hobby Catalog! ***96 value packed pages*** of the neatest goodies around with lots of new stuff! Order yours today on line or give us a call... Or download the PDF at www.ramseykits.com/catalog!

www.ramseykits.com

ramsey
www.ramseykits.com

590 Fishers Station Drive
Victor, NY 14564
(800) 446-2295
(585) 924-4560

800-446-2295

Where Electronics Is Always Fun!

✦ Build It! ✦ Achieve It!
✦ Learn It! ✦ Enjoy It!

■ BY CHUCK HELLEBUYCK

PROGRAMMING THE PICDEM 2 PLUS DEVELOPMENT BOARD

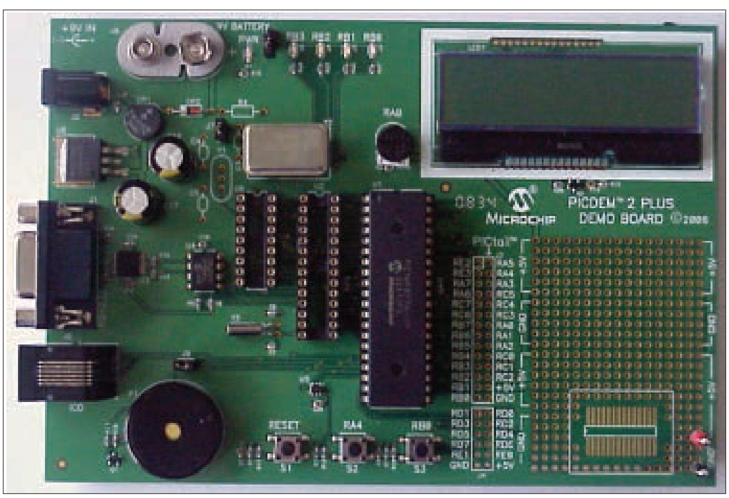
I received a message from a person who had purchased a Microchip PICDEM™ 2 Plus Development Board (see Figure 1) from www.microchipdirect.com but was confused on how to get started. The person thought this would be a great board to start with because of all the features it offers, including an LCD, EEPROM, piezo buzzer, LEDs, switches, potentiometer, and serial port. The board also has a voltage regulator and nine volt battery clip. I have to agree, it's a great board to start with. However, it was the "getting started" part that he was seeking help with. He wanted to program using the PICBASIC PRO™ compiler because he read about it here, but he couldn't find any PICBASIC PRO example code or documentation included with the board. I helped him with some sample code, but had to admit that it wasn't written specifically for the PICDEM 2 Plus board. He was happy with the help and is busy programming his board.

This led to a discussion with a friend about how quickly I could write some sample code dedicated to this development board. We made a list of possible project ideas, which included the following:

1. Flash an LED.
2. Scroll the four LEDs.
3. Drive the LCD.
4. Read a potentiometer with an Analog-to-Digital Converter (ADC).
5. Drive the piezo buzzer.
6. Sense the momentary switches.
7. External interrupt.
8. Read and write to EEPROM.
9. Communicate via RS-232.

After looking over the list, I estimated that I could write PICBASIC PRO code for all of these projects in less than four hours. The programs would be simple and would get the job done. They would also be simple enough to fit within the 31 command-line limit of the PICBASIC PRO sample version. The challenge was on. What I didn't tell my friend was that I planned to make maximum use of the example code that comes with the PICBASIC PRO sample version to start each project, and then just modify it to work with the PICDEM 2 Plus board. This would still require some work adjusting of the connections, but it would save me time compared to starting from scratch. This would still require some work adjusting the code for the PICDEM 2 Plus connections (shown in **Figure 4**), but it would save me time compared to starting from scratch. In the end, I altered the sample code quite a bit, but it was fairly easy to accomplish this challenge.

After getting everything set up — I used an MPLAB® ICD 2 for the programming tool because it is available bundled with the PICDEM 2 Plus board — I was ready to write some code. I was able to get all nine



■ FIGURE 1. PICDEM™ 2 Plus Development Board.

projects done in 3-½ hours with one catch: the RS-232 communication only worked in one direction. I could send a message to the PC, but I could not get the PC to properly send a message back. I used two different terminal programs and a USB to RS-232 cable, which appeared to be the problem. I eventually figured it out, but after hours of non-stop code development and trying to get the PC to send a message back, I decided to call it quits. After all, I had met 99% of the challenge, since I did get the PICDEM 2 Plus to *send* a message that displayed on the PC screen.

So, here are the routines for you to work with on your own PICDEM 2 Plus development board; or, they can be easily converted to any development board that has these features. This just proves how quick the PICBASIC PRO compiler makes code development. I won't go through all the details of each file as I normally do. I'll just write an overview for each project. I used a PIC16F877A microcontroller (MCU) for all of the projects, since it is a 40-pin part supported by the PICBASIC PRO sample version. The PICDEM 2 Plus demo board also connects the LCD to the PORTD pins of the 40-pin part. The board has sockets for 18- and 28-pin parts, but neither connects to the LCD since they don't have a PORTD. Hence, the 40-pin part was the winner.

FLASH AN LED

This has been done many times before, but it verifies that the hardware is hooked up properly and the PIC16F877A is running. Using simple HIGH and LOW commands saved me from even having to set the port-direction registers. These commands take care of that for you.

```
' Project 1 - Flash RB0 LED 1/2 second on,
' 1/2 second off

loop:   High PORTB.0     ' Turn on LED connected to
                         ' PORTB.0
        Pause 500        ' Delay for .5 seconds

        Low PORTB.0      ' Turn off LED connected
                         ' to PORTB.0
        Pause 500        ' Delay for .5 seconds

        Goto loop        ' Go back to loop and
                         ' blink LED forever
        End
```

SCROLL LEDs

The board has four surface-mount LEDs connected to PORT B pins 0 through 3. This project lights them in sequence back and forth. Using two For-Next loops made this an easy task.

```
' Project 2 - Scroll LEDS back and forth

B0       var      byte

loop:
For B0 = 0 To 3              ' Scroll LEDs Left
High B0
Pause 100
Low B0
Next

For B0 = 3 to 0 Step -1      ' Scroll LEDs Right
High B0
Pause 100
Low B0
Next

Goto loop
```

DRIVE THE LCD

A simple "Hello World" message was the program of choice. I displayed Hello on the first line of the 2x16 LCD display and then waited a half second before writing "World" in its place. This way, it showed one word at a time, as shown in **Figure 2**. The LCDOUT command worked great for this, but I did need to redefine the connections, which were different than the default settings. A set of Defines took care of that. The schematic showed that the LCD also had a transistor circuit that could turn the LCD on or off. This is not a typical connection for LCDs, but just adding a simple HIGH command to that connection made the LCD come to life.

```
' Project 3 - Driving an LCD Module in
' 4-bit mode
'
' LCD should be connected as follows:
'        LCD      PIC
'        DB4      PortD.0
'        DB5      PortD.1
'        DB6      PortD.2
'        DB7      PortD.3
'        RS       PortD.4
'        E        PortD.6
'        RW       PortD.5
'        LCDOn    PortD.7
'        Vdd      5 volts
'        Vss      Ground
'        Vo       Ground

' Define LCD registers and bits
Define   LCD_DREG    PORTD
```

■ FIGURE 2. LCD Display.

```
Define    LCD_DBIT     0
Define    LCD_RSREG    PORTD
Define    LCD_RSBIT    4
Define    LCD_EREG     PORTD
Define    LCD_EBIT     6

       Pause 500      ' Wait for LCD to startup
       High PORTD.7   ' LCDOn Set to 1 to turn
                      ' LCD On
       Low PORTD.5    ' R/W Write Only LCD Mode

loop:  Lcdout $fe, 1 ' Clear LCD screen
       Lcdout "Hello"' Display Hello
       Pause 500      ' Wait .5 second

       Lcdout $fe, 1 ' Clear LCD screen
       Lcdout "World"
       Pause 500      ' Wait .5 second

       Goto loop      ' Do it forever
```

READ A POTENTIOMETER WITH ADC

The potentiometer was wired to the AN0 pin of the PIC16F877A socket, so using the ADCIN command made this another easy task to complete. In fact, I used the LCD project code to display the results. In reality, this project just added a few command lines to the previous project. I used an eight-bit resolution result that worked perfectly. As the potentiometer is turned on, the ADCIN result is displayed on the LCD. If the pot was turned all the way counter-clockwise, then the LCD showed 0. If the pot was turned all the way clockwise, then the display showed 255. Any position in between was a value between 0 and 255.

```
' PICBASIC PRO program to display result of
' 8-bit A/D conversion on LCD
'
' Connect analog input to channel-0 (RA0)

' Define LCD registers and bits
Define         LCD_DREG      PORTD
Define         LCD_DBIT      0
Define         LCD_RSREG     PORTD
Define         LCD_RSBIT     4
Define         LCD_EREG      PORTD
Define         LCD_EBIT      6

' Define ADCIN parameters
Define         ADC_BITS      8 ' Set number of bits
                               ' in result
Define         ADC_CLOCK     3 ' Set clock source
                               ' (3=rc)
Define         ADC_SAMPLEUS 50' Set sampling time
                               ' in uS

adval   var   byte        ' Create adval to store
                          ' result
       Pause 500          ' Wait for LCD to startup
       High PORTD.7       ' LCDOn Set to 1 to turn
                          ' LCD On
       Low   PORTD.5      ' R/W Write Only LCD Mode

              TRISA = %11111111      ' Set PORTA
                                     ' to all
                                     ' input
              ADCON1 = %00000010     ' Set PORTA
                                     ' analog
              Low PORTE.2            ' LCD R/W
                                     ' line low
                                     ' (W)

              Pause 500        ' Wait .5 second

mainloop: ADCIN 0, adval   ' Read channel 0 to
                           ' adval

   Lcdout $fe, 1                      ' Clear LCD
   Lcdout "Value: ", DEC adval        ' Display the
                                      ' decimal
                                      ' value

              Pause 100               ' Wait .1
second

              Goto mainloop           ' Do it
                                      ' forever
              End
        End
```

DRIVE THE PIEZO BUZZER

The piezo buzzer on the board already had a simple drive circuit, so all the micro had to do was produce a square wave at a certain frequency. The frequency determined the pitch of the buzzer output. I tried several frequencies until I ended up at 1.25 kHz, to produce an alarm clock type buzz. The PICBASIC PRO Freqout command handled this easily, thus making this the shortest program of the bunch.

```
' Project 5 - Driving the Piezo to create an
' alarm sound
' Piezo connected to PORTC pin 2.

loop:
    FREQOUT PORTC.2,100,1250 ' Generate Alarm
    Goto loop                ' sound Forever
```

SENSE THE MOMENTARY SWITCHES

The development board has three momentary switches, but one of them is connected to the MCLR pin as a reset. I decided to use the other two that are connected to the RA4 and RB0 pins to light LEDs when they were pressed. The RA4 switch was labeled S2 and the RB0 switch was labeled S3. I tied these in software to the RB2 and RB3 LEDs, respectively. When the S2 switch was pressed, the RB2 LED lit up. When the S3 switch was pressed, the RB3 LED was lit. I didn't add any switch debounce, so this was a very simple use of the If-Then command to test the switches. The schematic showed that a 4.7K pull-up resistor is connected to both switches.

```
' Project 6 - Read momentary switches and light
' LEDs when pressed
' RB3 LED on when S3 pressed, RB2 LED on when
'
S2 pressed

led3 var PORTB.3

led2 var PORTB.2

S3    var PORTB.0
S2    var portA.4
```

```
input s3
input s2

loop:
If S3 = 0 then
high led3
else
low led3
endif

If S2 = 0 then
high led2
else
low led2
endif

Goto loop               ' Do it forever
```

EXTERNAL INTERRUPT

The S3 switch tied to the RB0 pin can also act as an external interrupt. This is because the external interrupt pin on the PIC16F877A is the RB0 pin. Therefore, all I had to do was use the PICBASIC PRO On Interrupt command to perform this function. I didn't do anything in the main loop of code except run a continuous loop. When the S3 switch was pressed, the program would interrupt that continuous loop and run the interrupt service routine at the "myint" label. I placed the piezo-drive code here so, when the switch was pressed, the piezo sounded an alarm. One catch though — that pull-up resistor interfered with the RB0 LED, thus preventing the interrupt from seeing a proper voltage level. I'm not sure why it only did this during the interrupt routine, but I found that disconnecting the jumper near the LEDs disconnected the RB0 LED and allowed the interrupt to function properly.

```
' On Interrupt - Interrupts in BASIC
'  Turn LED on.  Interrupt on PORTB.0 (INTE)
'  turns LED off.
'  Program waits .5 seconds and turns LED
'  back on.

      Input PORTB.0
      On Interrupt Goto myint ' Define
                              ' interrupt
                              ' handler
      INTCON = $90            ' Enable INTE
                              ' interrupt

loop:
       Goto loop              ' Do nothing
                              ' forever


' Interrupt handler
        Disable               ' No interrupts
                              ' past this point
myint:  FREQOUT PORTC.2,
         2000,1250            ' Generate Alarm
                              ' sound
        INTCON.1 = 0          ' Clear interrupt
                              ' flag
        Resume                ' Return to main
                                       ' program
      Enable
```

NOTE: The Microchip name, logo, HI-TECH C, and PIC are registered trademarks of Microchip Technology, Inc., in the USA and other countries.PICDEM and PICkit are trademarks of Microchip Technology, Inc., in the USA and other countries. All other trademarks mentioned herein are property of their respective companies.

READ AND WRITE TO EEPROM

The PICDEM 2 Plus board has a 24LC256 I²C EEPROM on board. After looking over the schematic, I decided to use the I2CREAD and I2CWRITE commands. I used the LCD code to display the results. The program simply writes 16 bytes of data to the external EEPROM. Then, it reads the data back one byte at a time and displays it on the LCD. The data stored is the address of the memory location, so address zero stores the value zero, one stores one, etc. The I²C commands make this very easy to accomplish. The 24LC256 is a 16-bit address EEPROM, so this code will only work with larger-memory EEPROMs that use a 16-bit address bus.

```
' Project 8 - Reading and Writing to External
' EEPROM
'
' Write to the first 16 locations of an external
' serial EEPROM
' Read first 16 locations back and display on
' LCD
' Note: For 24LC256 EEPROM
' LCD should be connected as follows:
'       LCD     PIC
'       DB4     PortD.0
'       DB5     PortD.1
'       DB6     PortD.2
'       DB7     PortD.3
'       RS      PortD.4
'       E       PortD.6
'       RW      PortD.5
'       LCDOn   PortD.7
'       Vdd     5 volts
'       Vss     Ground
'       Vo      Ground

' Define LCD registers and bits
Define   LCD_DREG     PORTD
Define   LCD_DBIT     0
Define   LCD_RSREG    PORTD
Define   LCD_RSBIT    4
Define   LCD_EREG     PORTD
Define   LCD_EBIT     6

W0     var   Word
B0     var   W0.byte0
B1     var   W0.byte1
W1     var   Word

Pause 500      ' Wait for LCD to startup
High PORTD.7   ' LCDOn Set to 1 to turn LCD On
Low    PORTD.5' R/W Write Only LCD Mode

For W0 = 0 To 15               ' Loop 16 times
I2CWRITE PORTC.4,
PORTC.3,$A0,W0,[B0]   ' Write each address to
itself
Pause 10              ' Delay 10ms after each
write
Next

loop:
For W0 = 0 To 15               ' Loop 16 times
I2CREAD PORTC.4,
PORTC.3,$A0,W0,[B0]   ' Read Memory
Lcdout $fe, 1, "Address: ",#W0,$fe, $C0,"Data:
",#B0                 ' Display Memory
Pause 1000
```

```
Next
Goto loop
```

COMMUNICATE VIA RS-232

This final project gave me the most grief and, really, it was the computer and not this program that caused the problem. The PICDEM 2 Plus board has an RS-232 level shifter on board and a DB9 connector. The problem is that my PC only has USB ports. I've used an RS-232 to USB converter cable before, but for some reason, it didn't want to cooperate with me this time. I could get the program to send a message to the PC — and hyperterminal running on the PC displayed the message properly — but it would not let me send a character back. I had the code completed and then spent 30 minutes trying to get the cable working. I know it had something to do with the setup of the terminal window, but I didn't want to fool with it as I was approaching the four-hour limit. I downloaded a second terminal program that claimed to work better than hyperterminal from the Internet, but no luck. I was about to try a PICkit™ 2 running the UART tool that is built in to the PICkit 2 programmer software, but ran out of time. The four hours was up, so I called it quits. In theory, I had the code written in 3-1/2 hours, but without getting the PC to communicate, I guess I officially failed the four-hour test. (That's why I call the project 99% successful.)

```
` SERIN & SEROUT Commands
`
` Upper case serial filter.

SO        var      PORTC.6      ` Define serial out
pin
SI        var      PORTC.7      ` Define serial in
pin
T2400     con       0           ` Set serial mode
B0        var       byte

loop:
    Serout SO, T2400, ["Enter a Number?",10,13]
    Serin SI,T2400,B0      ` B0 = input character
    Serout SO,T2400,["You Entered:", B0,
    10,13]                 ` Echo character
    Goto loop              ` Forever
```

After everything was written down and I reviewed it with my friend, he fired up his PC and, together, we sorted out the cable-communication problem. The code was written correctly, but the USB cable driver setup was the problem. Therefore, despite my shortcomings with

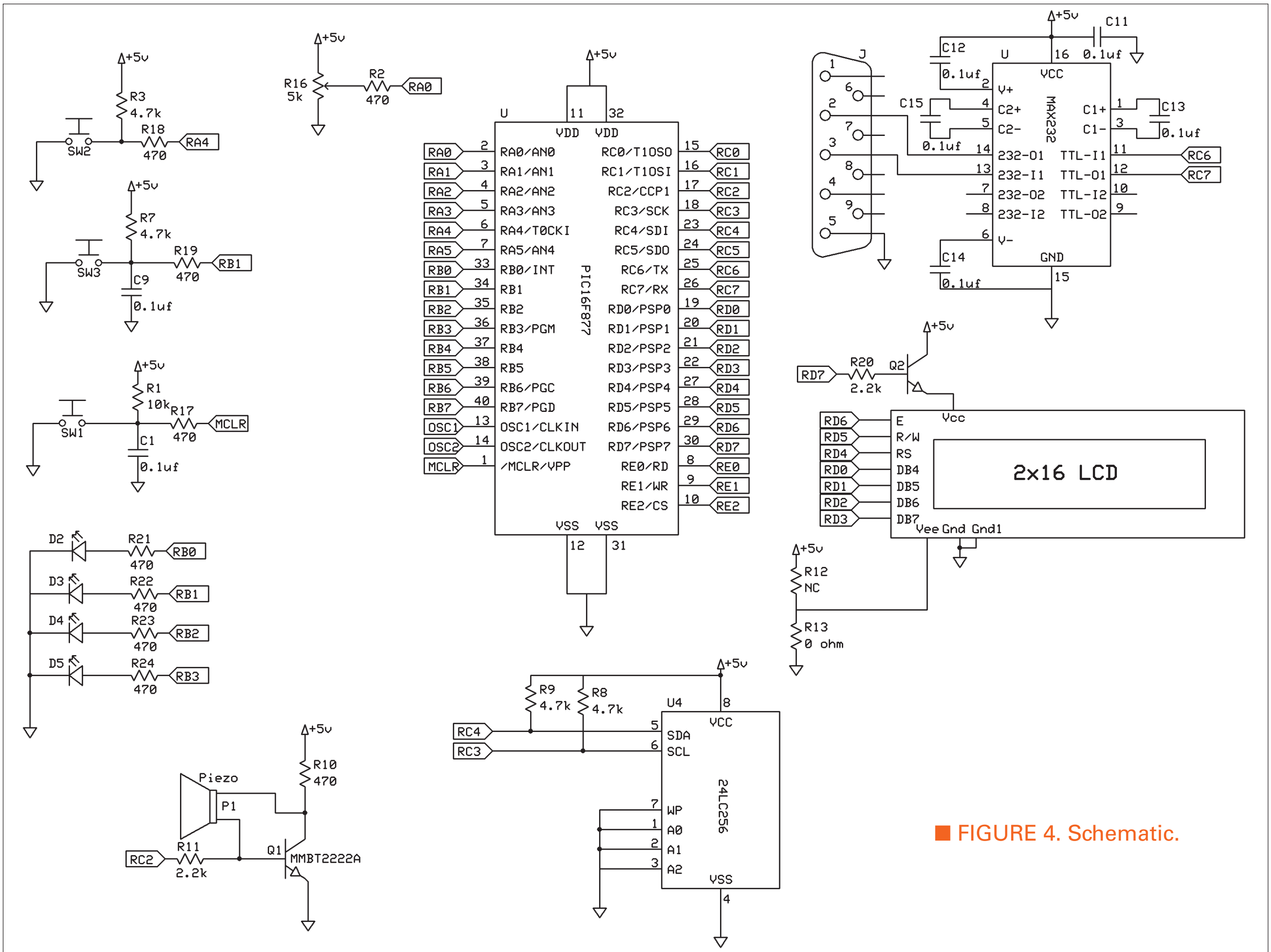
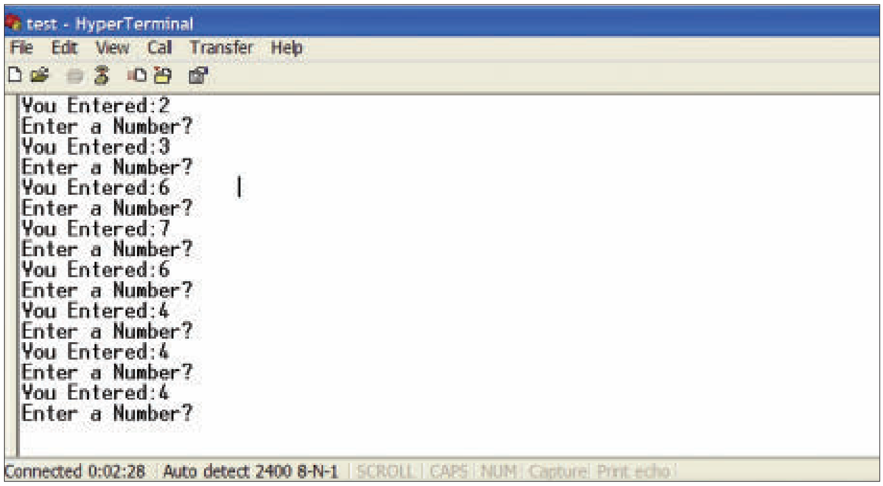


FIGURE 4. Schematic.



■ FIGURE 3. Terminal Program Window.

properly installing a driver on Microsoft® Windows® XP, I had completed all the code development in less than four hours, but never would have known without a little help from my friend. **Figure 3** shows the terminal program display with the code working properly.

CONCLUSION

Some readers will say I cheated by using the sample programs, but I argue that this was never a limitation to the challenge. I have found that many professional programmers pull sample code from their own libraries and sometimes from the compiler libraries in order to meet production deadlines. If you have a set of code functions already tested and proven, why reinvent the wheel and write again?

This was actually a fun article to develop. I've had one of the PICDEM 2 Plus boards sitting on my desk for months and never thought about writing PICBASIC PRO code for it. The board costs $99.95, so it's not the most inexpensive development board — I've seen similar boards sell for much more. You can also get this board from Mouser (**www.mouser.com**). The added feature of having the 28- and 18-pin sockets allows this board to be used for many different projects. You might consider this board for your home lab. It also has a temperature sensor that I didn't notice until after I created the list of projects. This would have been a great additional project, to make it an even 10. Now that this column is written, I can't help but consider expanding upon all this by explaining the code in more detail, and creating a starter booklet of sorts for this development board. That way, the next time someone asks me to help them with the PICDEM 2 Plus board and PICBASIC PRO compiler, I can offer them a complete set of guidelines. If you have any questions or comments, please send them to me at chuck@elproducts.com. **NV**

Q&A

WHAT'S UP:

Join us as we delve into the basics of electronics as applied to every day problems, like:

- ✔ **Solar Panel Voltage Regulator**
- ✔ **Op-Amps and Diodes**
- ✔ **Current Sensing Motor Control**

■ WITH RUSSELL KINCAID

In this column, I answer questions about all aspects of electronics, including computer hardware, software, circuits, electronic theory, troubleshooting, and anything else of interest to the hobbyist. Feel free to participate with your questions, comments, or suggestions.

Send all questions and comments to:
Q&A@nutsvolts.com

BALANCED MODULATOR

Q I want to adapt an old circuit from the June 1962 *PE Magazine*. It was designed for 40 and 75 meter bands but I want to use it on 200 kHz which means some values will have to be changed. In particular, I will need information to make L1, L2, L3, and L4. I want to experiment with this circuit for voice changer experiments. I think most of the values stay the same, but you know best.

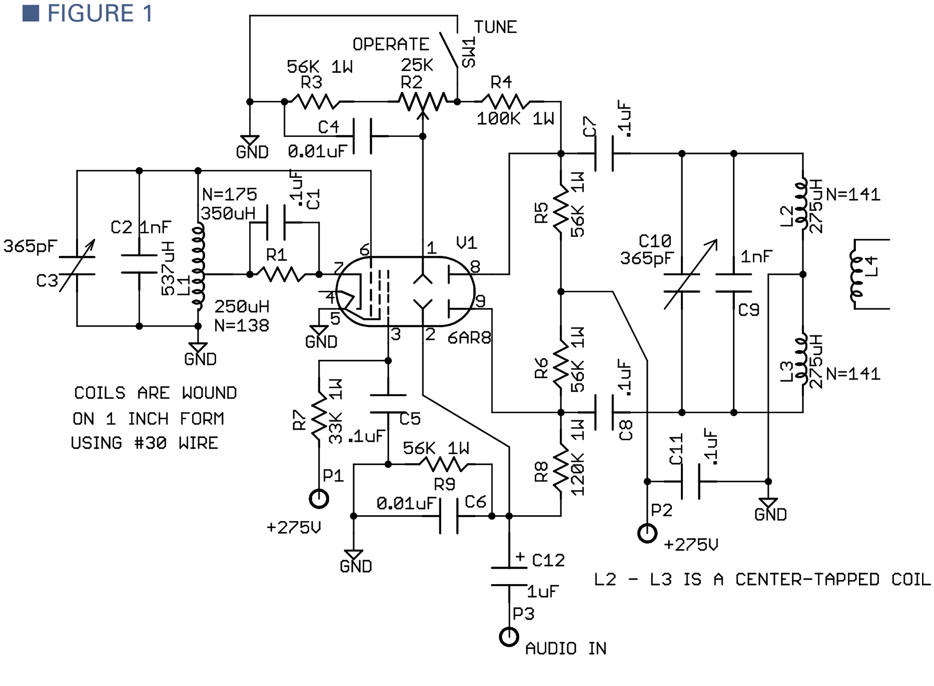
— Craig Kendrick Sellen

A It took me a while to figure out what to do with this. The oscillator was complex so I simplified it (see **Figure 1**). I don't think you need crystal control at 200 kHz. I didn't change the biasing because I don't know why it was done that way. I changed the output from a dual ganged tuning cap to a center-tapped coil because ganged capacitors will be hard to find. The 365 pF tuning cap is standard and provides enough range to tune the center frequency. L4 will be wound over L2–L3 but the number of turns will depend on the load requirements.

The tune switch throws the circuit out of balance so you can adjust C10 for max output with no audio input.

If you need a crystal controlled frequency, **Figure 2** is the oscillator part of the circuit. You can put a trim cap in parallel with the crystal if needed to pull the frequency lower. If it doesn't oscillate, make C1 smaller; the value that just makes it oscillate is best. The crystal can break if it is driven too hard, so L1 limits the crystal current. For 80 uH air core on one inch form, wind 60 turns #30; close wound.

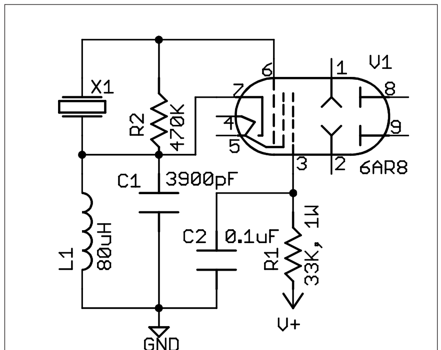
■ FIGURE 1



ANTENNA QUESTION

Q How do passive AM antennas work to boost weak signals? Also, could you explain how to build one, with formulas if possible?

— A.L., Nevada



■ FIGURE 2

A I'm no expert, but I will do my best. Antenna gain is usually referenced to a 1/4 wave dipole as zero dB. Six dB is a voltage gain of 2, and the voltage gain doubles every 6 dB; 24 dB is a voltage gain of 16, etc. Antenna gain is accomplished by either increasing the capture area or increasing the directivity, or both. The dipole antenna receives the signal from one direction but receives noise from all directions. If the antenna is directive, it reduces the noise so even though it has no gain, the signal to noise ratio is improved. The antenna works best when it is resonant. To be resonant, it must be some multiple of 1/2 wavelength. The 1/4 wave dipole works because there is a virtual 1/4 wave in the ground plane. The length in feet of a 1/2 wavelength wire can be calculated from: L=492*K/F where F is in mega MHz and K is a factor between .9 and .98, depending on the ratio of the wire diameter and the wavelength. For frequencies in the AM broadcast band, K = .98 in most cases.

For more in-depth information, I recommend The American Radio Relay League, Inc., book: *Basic Antennas*. The price is $29.95 and you can write to them at 225 Main Street, Newington, CT, 06111-1494. The 8 AM to 8 PM order hotline is: 1-888-277-5289.

14 VOLT, 30 AMP VOLTAGE REGULATOR

Q I live on my boat for six months of the year. During that six months, 95% of my electricity comes from solar and/or wind. I have a voltage regulator (store bought called a Flexcharger) which works well, but it is the type of regulator that when a set voltage is reached on the battery bank (set to 14.4 volts), the unit simply cuts off. Then, when another, lower pre-set voltage (12.7 volts) is reached, the unit turns on again. This on and off routine produces an annoying relay click (yes, I know, move the relay, but that isn't possible) and I end up turning off one solar panel at a time through the day to reduce the current charge, acting as a human voltage regulator (four panels in total, producing almost 500 watts).

What I would like is a voltage/current regulator that operates in three stages. First stage would be the bulk charge to a set voltage. Second stage would be the acceptance charge, which would maintain a constant voltage using varying current, until the set voltage again is reached. Third stage would be the float voltage to a preset voltage, usually around 14 volts. These type of regulators are in common use for high output alternators on boats for charging large house banks. I do have a large house bank on my boat, and would like a circuit for a three-stage regulator that could handle a maximum of 30 amps for solar use. The wind generator mentioned above has its own regulator built in, and is not an issue.

— Dennis Baut

A My interpretation of your requirements is that you want to maintain 14 volts at the battery and not overcharge it. A fixed voltage regulator will accomplish that; see **Figure 3**. The PNP/NPN arrangement allows the circuit to operate at very low voltage input. It will provide 14 volts output at 20 amps load with 15 volts input. My solar panel gives 18 volts in bright sun and 15 volts on a cloudy day (no load).

The LM4040 voltage reference is 1/2% and with 1% resistors, you won't need a trim pot to get 14 volts output within 2%. R4 and C1 are to prevent the circuit from oscillating at the transition frequency of the transistors. The parts list is **Figure 4**.

The 2N5883 and 2N5885 transistors are TO-3 packaged and will need to be bolted to a heatsink. A 6x6 inch or larger sheet of 1/8" marine aluminum would be good. The rest of the circuit can be built on perf board and mounted on standoffs on the heatsink. The 2N5883 will

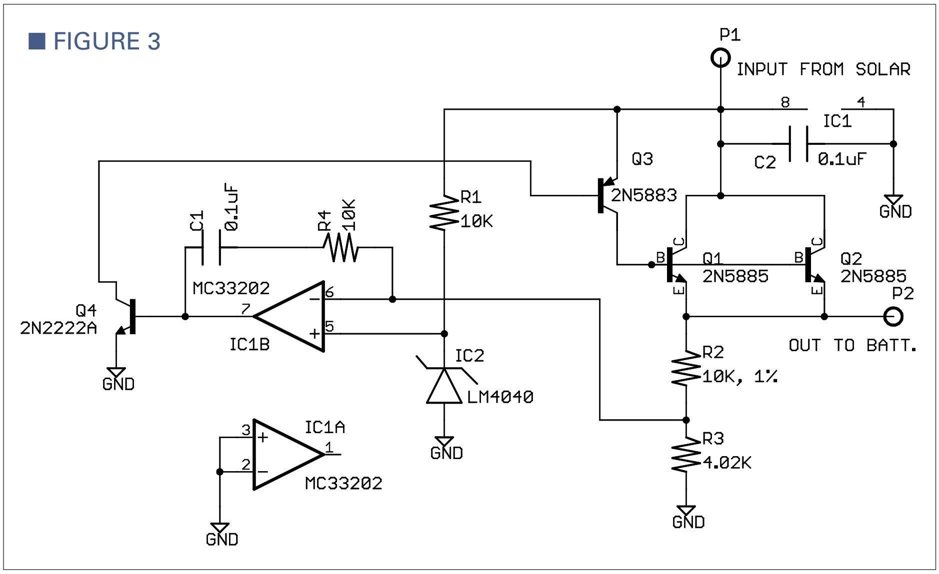
14 VOLT REGULATOR PARTS LIST

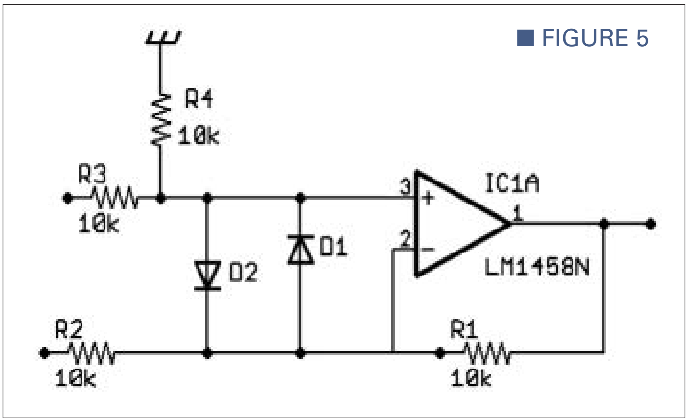
PART	DESCRIPTION	PKG	MOUSER PART #
IC1	DUAL OP-AMP RAIL/RAIL	DIP8	863-MC33202PG
IC2	REFERENCE, 4.096V	TO92	595-LM4040D41ILP
Q1, Q2	NPN, 25 AMPS, 30V	TO3	863-2N5885G
Q3	PNP, 25 AMPS, 30V	TO3	863-2N5883G
Q4	NPN GEN. PURP.	TO92	863-PN2222ARLRAG
C1, C2	0.1 µF, 50V	RADIAL	80-C320C104K5R
R1, R2, R4	10K, 1%, 1/4W	AXIAL	271-10K-RC
R3	4.02K, 1%, 1/4W	AXIAL	271-4.02K-RC

www.mouser.com

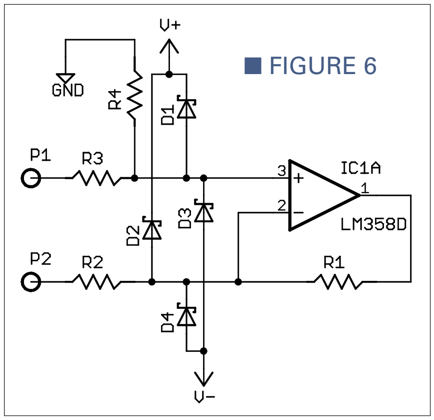
■ FIGURE 4

■ FIGURE 3





■ FIGURE 5



■ FIGURE 6

need to be insulated but I would fasten the 2N5885s directly to the heatsink using heatsink compound.

CROSSTALK PROBLEM

Q I am using an Arduino (a platform programmable in C or C++) to monitor for several conditions: vehicle detected, garage door open, shop door open, lightning. The lightning detector is required to suppress the vehicle detector alerts — the vehicle detector is magnetometer-based and lightning triggers it. All the inputs to the Arduino are 5V/ground. Whenever a status change is detected, the Arduino sends a UDP message to a solid-state PC (running Linux) which plays an appropriate WAV through the house alarm speakers.

My problem is crosstalk, I think. The shop door line runs through a phone cable. When the phone rings it sets off the door alert (many times!) When the garage door is opened, it triggers the driveway event message. I need some general guidelines on suppressing the problem. Do I need shielded cables everywhere? Would ferrite inductors help? Capacitors to ground? I am a software type; I am over my head on the electronics.

— Harvey Lewis

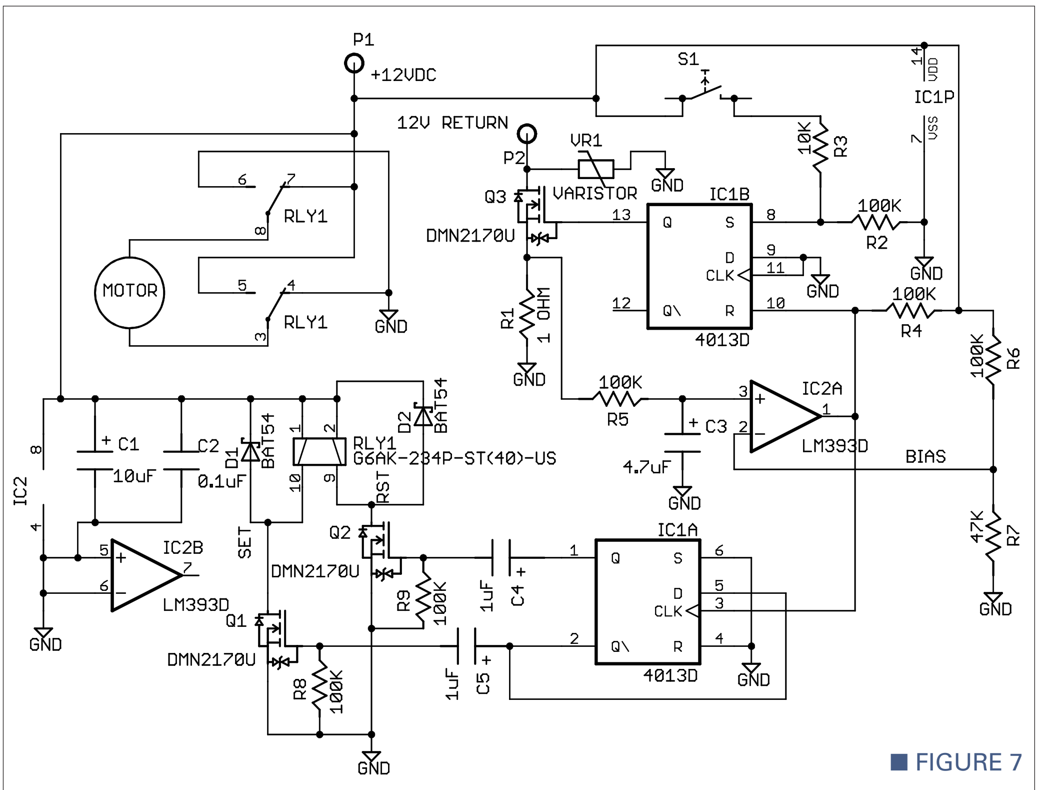
A The first line of defense would be to put a resistive load on the line at the Arduino input; however much the sensor can drive and still produce a logic high (3.5 to 4 volts). Shielded cables (two wires with shield) would be appropriate on those lines that are still having a problem. The shield should be connected to ground on one end only; I think the Arduino end would be best. I don't think ferrite beads would provide enough inductance to help but a capacitor to ground at the Arduino input would work if the signal is a pulse lasting 100 mS or so. I would try 0.01 µF to start, and go smaller if it kills the sensitivity.

OP-AMP QUESTION

Q I have been told that in an electrically noisy environment, it is a good idea to place two diodes in parallel and back to back across the two input pins of an op-amp (as shown in **Figure 5**). This would not be done if the op-amp were used as a comparator. I have not read of this practice. What do you think?

— Richard Gagnon

A I assume the signal is connected to R2 and R3, in which case the diodes will provide a little protection if the signal greatly exceeds the IC capability, but does not protect against common mode signal where both inputs go high or low, exceeding the power supply voltage (lightning, for example). The arrangement of



■ FIGURE 7

Figure 6 is better because it does not limit the signal but prevents the inputs from greatly exceeding the power supply voltage. This adds capacitance to the op-amp input which could be a problem is some cases.

CURRENT SENSING MOTOR CONTROL

Q I am planning on using a small 12 volt DC gear motor to raise and lower a small alb jack. This is a scissor type jack with a platform on top. The jack needs to stop at only two points — upper and lower — but precision and repeatability are important.

Instead of using microswitches to set the limits, I was thinking of bolting on hard stops and using a circuit that would monitor the motor's current draw. The spike in current when the motor stalled would then kill the power. Two momentary push-button switches (up/down) could be used to control the circuit. Any ideas?

— Walter Maslowski

A After kicking this around in my mind for a while, I came up with the circuit of **Figure 7**. The relay is a latching type with the DPDT contacts arranged in the typical reversing circuit. The motor is started by pressing S1, a momentary push-button, which makes Q of IC1B high, which turns on Q3. The motor startup current will be nearly equal to the stall current, so R5 and C3 are provided to keep that pulse from resetting IC1B. When the jack hits the stop, the stall current through R1 will drive IC2A output high and reset IC1B. At the same time, IC1A is clocked, causing the relay to switch the motor direction. Since the relay switches in milliseconds and Q3 switches in microseconds, there is not a problem of the motor reversing too soon. The relay only needs a 5 mS pulse to switch it, so I put the R-C at the gate of Q1 and Q2 to save power.

I assumed that the running motor current was 100 mA and the stall current to be one amp. If this is way off, you will need to adjust some circuit values. When you build the circuit, leave IC2 out so you can measure the stall voltage across R1. Make the bias voltage 1/2 of the stall voltage. R7 (in K ohms) = BIAS/0.12 mA will be close enough. If there is a problem with the motor startup current flipping IC1B, make C3 larger.

VR1 is a five volt MOV (metal oxide varistor) to protect Q3 from the motor transients. All the parts are surface-mount except the Omron relay which will plug into a DIP socket. If you want to use through hole parts, you can substitute 2N7000 or BS170 for Q1 and Q2. Use two of them in parallel for Q3. For D1 and D2, 1N4148 will work. The five volt varistor is not generally available in through hole, so I recommend using 1N4735A, a 6.2 volt zener. **NV**

MAILBAG

Dear Russell:

RE: 4-20 mA current loop temperature sensor, June '09, page 29. There are several aspects of your design that I like, in particular the use of two transistors as opposed to a single transistor. However, the cal trim circuit is not like any I have ever seen. Your zero will be greatly dependent on the voltage of the loop. In most loop applications, the power supply is not tightly regulated so this design wouldn't work very well in an industrial application. It would be better to use a precision, low current reference, such as a MAX8069, to power the cal trim pot.

The other part of the circuit that I believe could be improved on is the inability to offer any adjustment for span. I have never tried an LED as a voltage dropping element but I wonder if the current through the device is constant enough relative to temperature so as not to cause inaccuracy in the overall calibration. I have attached a schematic of a circuit that I have used with great success in the past (**Figure A**). I designed the circuit in the early 1980s but I am sure that several designs are almost identical. You will notice that I offer a span and zero adjust, and that the value of the current sense resistor is a bit more standard. In my design, the zero and span do interact but it only takes about five iterations to achieve proper span and zero if the potentiometers are set to 50% at start. The values in (Figure A) should be close for the circuit example in your article. I have not bread boarded this circuit but I did SPICE simulate the design and it appears to work as I remember.

Thanks for your article every month. I always look forward to your replies to the questions.

— Jeff Perryman

Response: Thanks for the feedback, you are so right! I should have put a voltage regulator across the cal trim pot. I did not see the need for a span adjustment because the current sense resistors can be 0.1% and provide sufficient accuracy. I really don't like interacting trims; particularly in a production environment (this was one of a kind, however). The LED is like a low voltage zener, only better. It does vary with temperature but that will not be a problem in this circuit if the voltage regulator that you recommend is used.

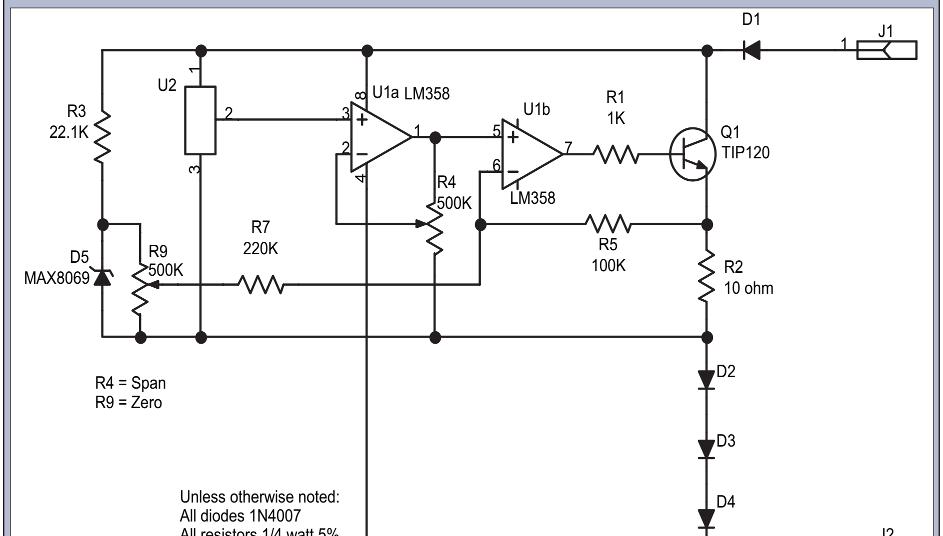
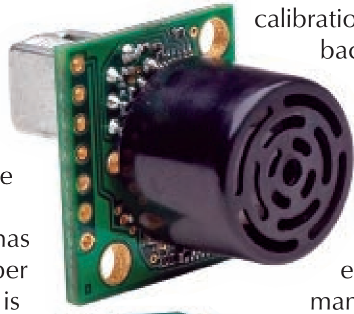


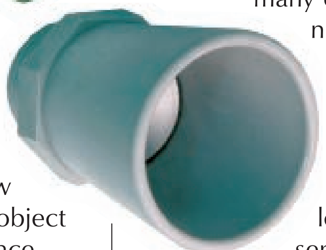
FIGURE A

NEW PRODUCTS

- HARDWARE
- SOFTWARE
- GADGETS
- TOOLS

SMALL INDUSTRIAL ULTRASONIC SENSORS PACK A BIG PUNCH





The XL-MaxSonar® line of MaxBotix, Inc., ultrasonic range sensors has arrived. This low cost, super high performance sensor is available in both indoor and outdoor versions. The XL-MaxSonar sensor line maintains the same look and feel of the existing LV-MaxSonar sensor line, with small size, low power, stable range readings, object detection to the front sensor face, and more, but now has more reliable distance readings. The line also has fully automatic real-time background calibration, much higher acoustic output power, greatly improved real-time noise rejection, centimeter resolution, longer distance range measurement, and for some models real-time analog envelope output and various analog hardware gains from 250 to 4,000. These features result in virtually noise-free distance readings for most users. The XL-MaxSonar sensor line is available with factory calibrated beam patterns. The indoor and outdoor sensors retail for $54.95 and $104.95, respectively.

The real-time fully automatic calibration happens in the background, so that for every range reading, the sensor is calibrated to operate properly for that individual reading. Even if the sensor is powered up with an object pressing against the front sensor face, the presence of the object will be reported correctly. If during operation, the power supply voltage drops (range of 3.3V to 5V) or if the temperature changes (range of –40°C to +65°C), the automatic calibration runs in the background and sets the parameters for the sensor to operate correctly.

The high acoustic power allows for the ultrasonic energy to effectively overpower many outside acoustic noise sources. This allows for proper operation in many environments such as micro UAV vehicles, where a lower powered sensor would be unusable.

The XL-MaxSonar products now reject noise with equal effectiveness, independent of hardware or software gain. The real-time filtering of the analog envelope is held to a new standard. For all the products in this sensor line, for regular continuous noise sources such as motors and vibrations found on robots and UAVs, the sensor learns and then removes the noise, allowing reliable readings. In addition, when the engine noise increases or an additional noise source comes into play, the filtering learns and changes to compensate.

With increased acoustic power, auto calibration, and better noise filtering, the products allow for stable distance readings with centimeter resolution. In addition, the higher power allows for longer range measurements.

The real-time analog envelope provided to the user is taken directly from the end of the analog chain of the product. The output is the log compressed voltage output of the acoustic return signal. When powered with five volts, the sensors compress the waveform into an analog output range of about three volts. Most users will only use this to verify product installation and operation, but users may desire to perform their own signal processing. Users wanting long-range or details outside the central field of view, will choose a higher gain product.

For more information, contact:
MaxBotix, Inc.
Tel: **218-454-0766 ext. 2**
Fax: **218-454-0768**
Web: **www.maxbotix.com**

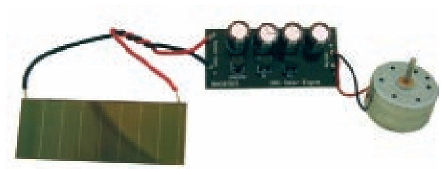
SRI-04 X10

SPEECH RECOGNITION INTERFACE

The X10 Speech Recognition Interface SRI-04 from Images is an interface board for the SR-06 and SR-07 speech recognition circuits. The interface allows the speech recognitiion kit to output on-off commands via a X10 power line interface (PL513). The interface can control up to 16 Control modules (X10) on any of the 16 available house codes. Price is $79.95

SE-02

The 1381 solar engine kit from Images stores electrical power



from the sun.

When enough power is stored, the circuit dumps the stored electrical power through the circuit load; in this case, a motor.

The kit may also be used with BEAM and Solarbotics style robots. Price is $19.95.

For more information, contact:
Images Scientific Instruments, Inc.
109 Woods of Arden Road
Staten Island, NY 10312
Tel: **718-966-3694**
Fax: **718-966-3695**
Web: **www.imagesco.com**

SHOW US WHAT YOU'VE GOT!

If you have a new product, please email a short description and a photo of your product to:
newproducts@nutsvolts.com

SHOWCASE

MAGNETIC PENDULUM

BY TONY GASPAROVIC

Here's a really fun project that will get a lot of attention. It's an electronic pendulum that operates on the principle of magnetism. You've probably seen similar devices at office supply or novelty stores. I've owned a few of these over the years and was always amazed by them. Unfortunately, they never worked very well or would stop running after a few days. I searched all over the Internet looking for a better model, but I couldn't find one so I decided to make my own. After many months of testing and experimentation, I have come up with a stable and robust circuit that is easy to build and will run for months on two AA batteries.

■ Pendulum in action.

Theory of Operation

The timing of this circuit is controlled by the magnet. As the magnet crosses over the top of the electromagnet (the coil), it creates a small EMF voltage spike. This voltage spike is detected and amplified by transistor Q1. The output of Q1 causes Q2 to switch on, which turns on the electromagnet. The force generated by the electromagnet gives the magnet a push at the precise time it passes over the electromagnet, which keeps it swinging. With each pass of the magnet, the electromagnet pushes the magnet higher. When the magnet swings beyond the edge of the electromagnet, the EMF voltage drops to zero. The electromagnet turns off and the magnet continues to swing through the pendulum arc undetected, until it passes over the electromagnet again.

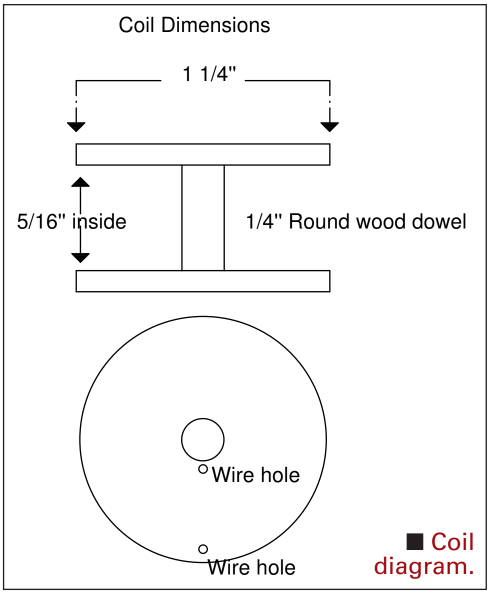
Construction

It's best to make the base from wood. When constructing the base, don't use any steel nails or screws. This will cause the magnet to be attracted to the metal and will hinder the smooth swing of the pendulum. Use brass or stainless steel hardware. Keep in mind the base should be at least as long as the pendulum arm. This will help keep it stable. The weight of the pendulum arm should be light so it will swing with as little resistance as possible.

I've had success having the pendulum arm swing from a loose-rolling skateboard bearing, or you can have the magnet swing from thread. If you're going to use thread, I recommend using upholstery thread because it is very strong. You will also need to mount the magnet in such a way to keep the pole of the magnet in line with the coil. You don't want the magnet to wobble, bounce, or tilt. The magnet that I am using has a 1/4 inch hole in it. You can glue a two inch piece of 1/4 inch dowel in the hole of the magnet and then drill a small hole in the other end of the dowel for attaching the thread.

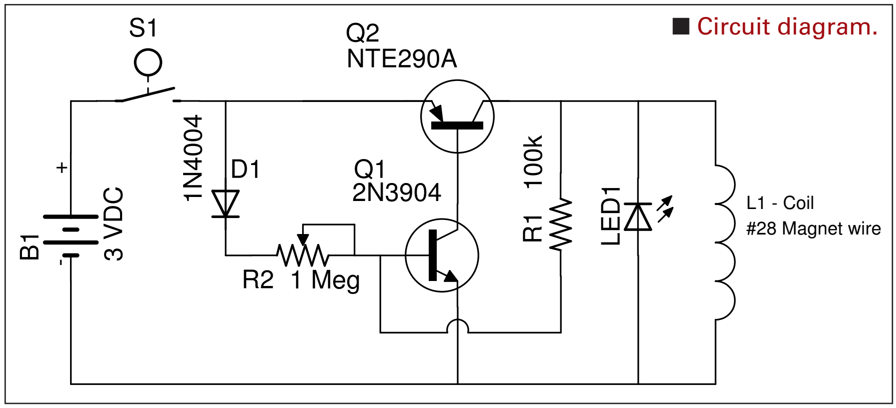
Building the Circuit

The circuit is very simple to build. I used a general-purpose RadioShack circuit board. There is one



■ Coil diagram.

detail that is important when soldering Q1: When you have a coil turning on and off in a circuit, you sometimes have to deal with oscillations or ringing. To fix this problem, solder the base of Q1 to a few long, unused circuit traces on the bottom of the circuit board. Since the circuit board that I used has a large, thick circuit trace running around the edge of the board, I soldered a small jumper from it to the base of Q1. Mount the circuit board on the base as far from the magnet as possible.



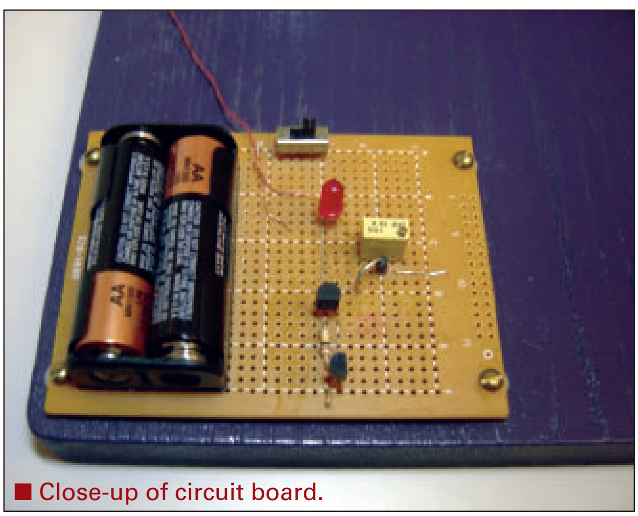
■ Circuit diagram.

PARTS LIST

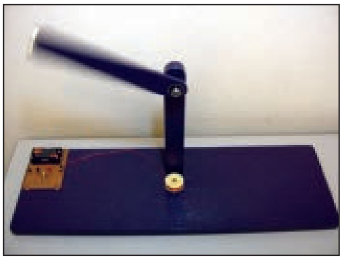
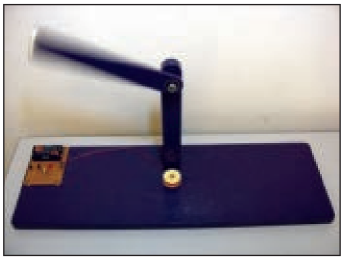
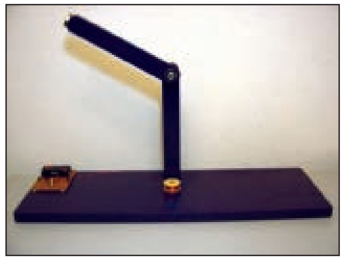
ITEM	DESCRIPTION	PART NUMBER
❑ R1	100K ohm resistor	RadioShack #271-1126
❑ LED	1 Red LED	RadioShack #276-307
❑ R2	1 mega ohm 21-turn variable trimmer	Spectrol 64W1M-K
❑ S1	Slide switch	RadioShack #275-406
❑ D1	Diode 1N4004	RadioShack #276-1103
❑ Q1	NPN transistor 2N3904	RadioShack #276-2016
❑ Q2	PNP transistor NTE290A	Newark
❑ N/A	AA battery holder (two cells)	Philmore BH910
❑ B1	2 AA batteries	RadioShack
❑ N/A	Circuit board	RadioShack #276-168b
❑ N/A	1-1/4 x 1/8 inch plywood disks for coil	Craft store
❑ N/A	1/4 inch wood dowel	Craft store
❑ N/A	Wood for base (I used 22 x 7 x 3/4)	Home Depot
❑ N/A	Round neodymium ring magnet N48 1 x 1/4 with 1/4 hole (buy on eBay)	
❑ N/A	Skateboard bearing	Local skateboard shop
❑ N/A	Upholstery thread	Craft store
❑ N/A	Steel bolt with locking nuts	Home Depot
❑ N/A	Small pan head wood screw for mounting magnet	Home Depot
❑ N/A	1-1/2 lb spool 28 gauge magnetic wire	Philmore 12-1228

Building the Coil

You can build the coil out of just about any type of insulated material. Wood, plastic, and fiberglass all work fine. Cut the coil ends using a hole cutter or buy them at a craft store. Most hole cutters have a center guide drill that is 1/4 inch. Insert a piece of 1/4 wooden dowel into the center hole of both 1-1/4 disks. Space the disks 5/16 inches apart (inside measurement), then glue them in place with super glue. Next, drill two small holes in one of the disks for the wire ends. The first winding should pass through the hole closest to the center of the coil. Give yourself about a two foot leader. Roll up the end of the wire and tape it to the end of the coil form. This is to protect it from damage during the rest of the winding process. I recommend using an electric drill to wind the coil. Here's a tip: Attach the end of the wooden


■ Close-up of circuit board.


■ Getting ready to swing.


■ Sequence of magnetic pendulum on bearing.

dowel to an electric drill.

Wind the coil with #28 magnetic wire. Wind the coil about 90% full. The completed coil resistance should be about 9-10 ohms. If your coil resistance is more than 10 ohms, you should remove some windings. When winding your coil, it's important to keep the windings as tight and straight as possible. (Yes, neatness counts!)

After the coil is complete and the resistance tested, spray a clear urethane over the coil wire to keep the windings from coming loose. Use a razor blade to scratch off the insulation from the ends of the coil wire. Be careful not to nick or damage the wire.

Turning It On for the First Time

Before turning on the circuit, adjust R2 to its maximum value with a small screwdriver. Install a fresh set of AA batteries. Turn the switch to the on position. Push the magnet across the coil. The LED should blink when the magnet crosses the coil. If so, congratulations! Your pendulum circuit is working. If not, you need to verify that all the components in the circuit are properly connected (polarity of all components). Next, stop the magnet from swinging. The LED should be turned off now. The next step will be to adjust the switching threshold.

Give the magnet a very small push. Adjust R2 slowly until you see the LED start to blink. Now, stop the magnet. The LED should turn off completely. It's important that the LED turns off completely when the magnet is not moving over the coil. This insures the coil is being turned off. Failure to adjust R2 correctly will cause limited battery life and poor operation.

Testing

I have done a lot of experimentation and testing with this pendulum circuit. The circuit design and the neodymium magnet that I have selected work very well together. I tried different coil sizes, number of turns, and other size wires. None of those modifications gave better results than I got with my final product.

Magnet Safety

The neodymium magnet that is used in this project is extremely powerful. It can pinch fingers or shatter when attracted to another object. For this reason, I don't recommend small children playing with it. Also, keep the magnet away from computers, floppy disks, credit cards, wind-up watches, etc. **NV**

NOTE

To see my pendulum running, go to
youtube.comhttp://www.youtube.com/watch ?v=4xTjlzzbXTQ.

BICYCLE GEAR POSITION INDICATOR

BY DAN GRAVATT

■ FIGURE 1. Prototype linear potentiometer sensor mounted on my road bike. Note the "span" potentiometer attached to the sensor.

Here's a couple of simple circuits to tell you what gear your bicycle is in while you're pedaling down the road. I usually check what gear I am in by looking down at the front and rear gears. I decided I needed a better way after I bought a good road bike with 30 (!) gear combinations (three gears in front and 10 in back). The rear gears are very closely spaced, and I was taking my eyes off the road for too long to count them.

Since I have more than one bike, I wanted a device which would work for all bikes that use derailleurs, regardless of the brand of bike or derailleur, and would work for up to three front gears and 10 rear gears. (I've never heard of a bicycle with more than that.) I found some shifters with mechanical gear indicators built in, and some add-on electronic gear position indicators (such as Shimano's Flight Deck system) for specific types of shifters, but nothing that would work with the bikes I had. I set out to build one myself.

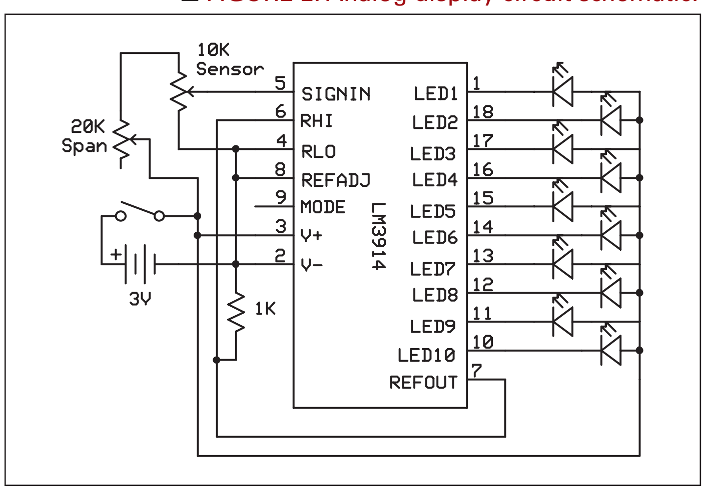
Sensor Selection

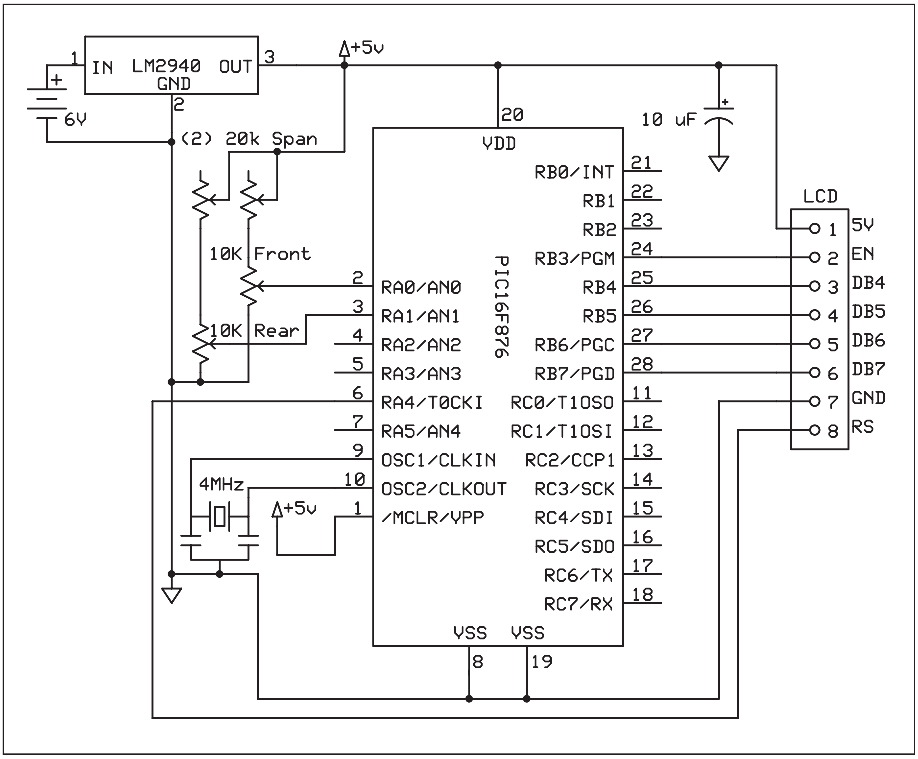
At first, I thought I would detect the chain position with an array of magnetic or optical sensors; one for each gear. This would theoretically be the least error-prone way of finding the chain, but I wasn't able to come up with a reliable design which would accommodate different numbers of gears or different spacing between the gears. I realized that the only constant across all the different types of gears and derailleurs was the step-wise movement of the control cable between the derailleurs and the shifters. A single linear position sensor attached to the derailleur cable seemed to be the way to go. I dug a linear potentiometer out of the junk box, attached it to my road bike (**Figure 1**), and found that the resistance changed in nice even steps as the derailleur moved.

Analog Display Circuit

The simplest method I could come up with for displaying the gear position was a row of LEDs (one for each gear). I needed to make the varying voltage input from the resistive sensor turn on the appropriate LED, and the obvious choice for the job was the LM3914 linear bar-graph display driver. **Figure 2** shows the schematic of the analog display with the linear potentiometer sensor. The LM3914's dot/bar input is left unconnected to produce a dot-mode display. The input circuit is

■ FIGURE 2. Analog display circuit schematic.





■ FIGURE 3. Digital display circuit schematic.

configured to use a minimum of external components and relies on the LM3914's internal voltage reference. Note the "span" potentiometer in the circuit — this adjustment is needed to align the step-wise movement of the derailleur with the LM3914's internal voltage divider.

Because of the wide supply voltage range of the LM3914, two AA or AAA batteries are all that is needed for a power supply. Make sure to use high efficiency, high brightness LEDs like those in the Parts List to ensure that the display is readable in direct sunlight. A sun shield may be added if desired for maximum readability, as well as a label with the gear numbers printed next to each LED.

As with most very simple designs, this one has some limitations. First, it can only display the position of one derailleur (front or back), so you would need two of these circuits for a complete gear position display system. The second limitation has to do with how linear your linear potentiometer is and how closely your gears are spaced. The 10-speed rear gear cassette on my road bike uses a narrow spacing and is only 1-3/8 inches wide. The junk-box linear potentiometer I used for the prototype was not linear enough to accurately indicate all 10 gears. No matter how I adjusted the span potentiometer, I could only register nine gear positions. On the other hand, when I installed the same linear potentiometer on my mountain bike, it was very easy to get the display to read correctly. My mountain bike has a seven-speed rear gear cassette with a normal spacing of 1-1/4 inches wide. It appears that for bicycles using normal spacing on their gears, you are unlikely to run into this limitation.

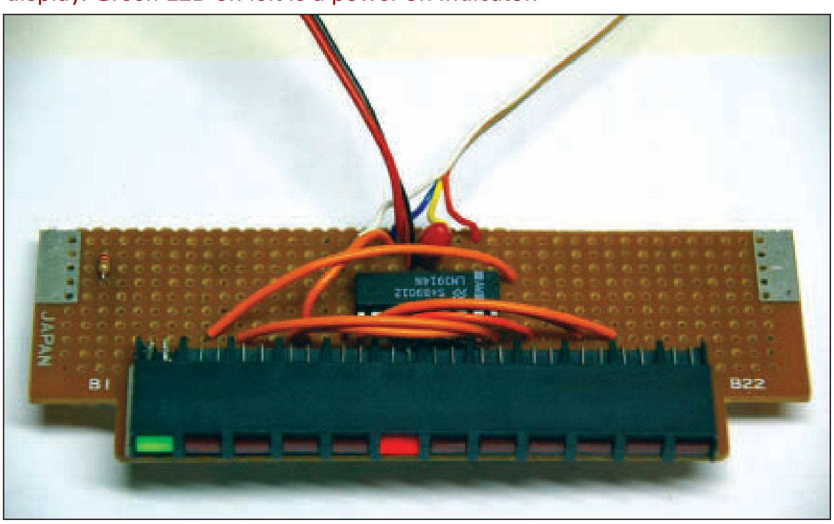
Digital Display Circuit

In order to overcome these two limitations, I designed a digital display circuit (**Figure 3**) based on the PIC16F8761. Two of the PIC's analog inputs are used to read the positions of the front and rear derailleurs simultaneously. A parallel-interface, liquid-crystal display with an HD44780 driver is used to show both positions and the overall gear (i.e., front gear 3 and rear gear 7 = 21st gear).

The code for the PIC can correct for any nonlinearity in your linear potentiometers by adjusting the widths of each input interval to the values from the potentiometer. Listing 1 (available on **www.nutsvolts.com**) shows that the main part of the code is a series of if-then statements assigning a particular input interval to each gear position. Each of these input ranges can be tailored to the specifics of your derailleurs and linear potentiometers to produce an accurate and repeatable indication of all gear positions. The code in Listing 1 contains default values for each input interval which should work fine if your linear potentiometers are indeed linear.

As shown in Figure 3, there is a span potentiometer with each linear potentiometer just like the analog circuit. Use the span potentiometers first to coarsely align the derailleur movement with the default values

■ FIGURE 4. Prototype analog gear position indicator display. Green LED on left is a power-on indicator.



the code assigns to each gear. If the span potentiometers can't give you correct readings across all gears, you can then tweak the input intervals in the code as necessary.

Unlike the LM3914, the PIC and the LCD can't simply run on two AA batteries. Four AA or AAA batteries and a low-dropout five volt regulator form the power supply for the digital display.

PARTS LIST

PARTS LIST (DIGITAL DISPLAY)	DIGI-KEY PART NUMBER (EXCEPT LCD)
❑ (1) Two-line by 24-character parallel-mode LCD	All Electronics LCD107 or LCD113
❑ (1) PIC16F876 microcontroller	PIC16F876A-I/SP-ND
❑ (1) 4 MHz ceramic resonator with capacitors	X902-ND
❑ (2) 10K linear potentiometers	P12338-ND
❑ (2) 20K trimmer potentiometers	D1AA24-ND
❑ (1) Five-volt low-dropout regulator	LM2940CT-5.0-ND
❑ (1) 10 µF capacitor	P5178-ND

PARTS LIST (ANALOG DISPLAY)	DIGI-KEY PART NUMBER
❑ (10) High-brightness red LEDs	160-1652-ND
❑ (1) LM3914 display driver	LM3914N-1-ND
❑ (1) 10K linear potentiometer	P12338-ND
❑ (1) 20K trimmer potentiometer	D1AA24-ND
❑ (1) 1K 1/8 watt resistor	1.0KEBK-ND

Construction and Installation

Layout and construction of both displays are non-critical, as shown by my first prototype of the analog display (**Figure 4**). Make sure your finished product is small enough to fit your handlebars without obstructing your brakes or shifters; rugged enough to withstand bumps and shocks as you ride; and as weatherproof as possible. The linear potentiometers can be mounted anywhere along the derailleur cables, with the wires routed along the frame to the display unit. A combination of zip ties and double-sided foam tape works well for attaching the sensor to the frame and the cable to the sensor lever. Secure the wires with zip ties so they don't get tangled in any moving parts, and leave some slack where the wires cross from the frame to the handlebars.

The linear potentiometers must be weatherized to prevent entry of water and dirt. One method of doing this is with a length of thin-wall flexible tubing (such as shrink tubing) large enough to fit around the sensor and the frame member it's attached to. Slit the tubing lengthwise, place it over the frame member and sensor, then seal the ends and the slit, leaving enough space for the cable and the sensor lever to move freely inside.

Future Directions

The LCD I used in this project (two lines by 24 characters) is physically pretty large for this application, but it leaves room for display of more data in the future. One idea I'm considering is putting the actual gear sizes into the code so it can calculate the gear ratios. If you want to keep things simple and have a smaller display, you could modify the code slightly to go with a display as small as 1x8 characters and a display format such as F:# R:##, where ## is the gear number.

Any way you build it, you'll have a useful tool for your bicycle which will help you keep your eyes on the road. **NV**

Contact the Author

Dan Gravatt is a licensed geologist in the state of Kansas. He can be reached at dgravatt@juno.com.

Footnote 1: Programmed PIC16F876s are available from the author.

THE REFUSEABLE BOX

BY RON NEWTON

This project was built for field troubleshooting and replaces blown fuses until the problem is solved. By dialing in the amperage, you can preset the drop-out point in the place of a fuse (200 mA – 5 amps). It is also known as a programmable relay. It displays the active AC or DC amperage being drawn when in the circuit.

There are units available that do this but the cost is in the range of $100 and up and they don't display the active amperage. It uses a Microchip PIC16F690 and can be programmed using a PICkit2 after it is soldered to the board. Cost is about $35.

How It Works

Both AC and DC currents are passed through a five amp bridge. When measuring AC, the diode provides full wave rectification.

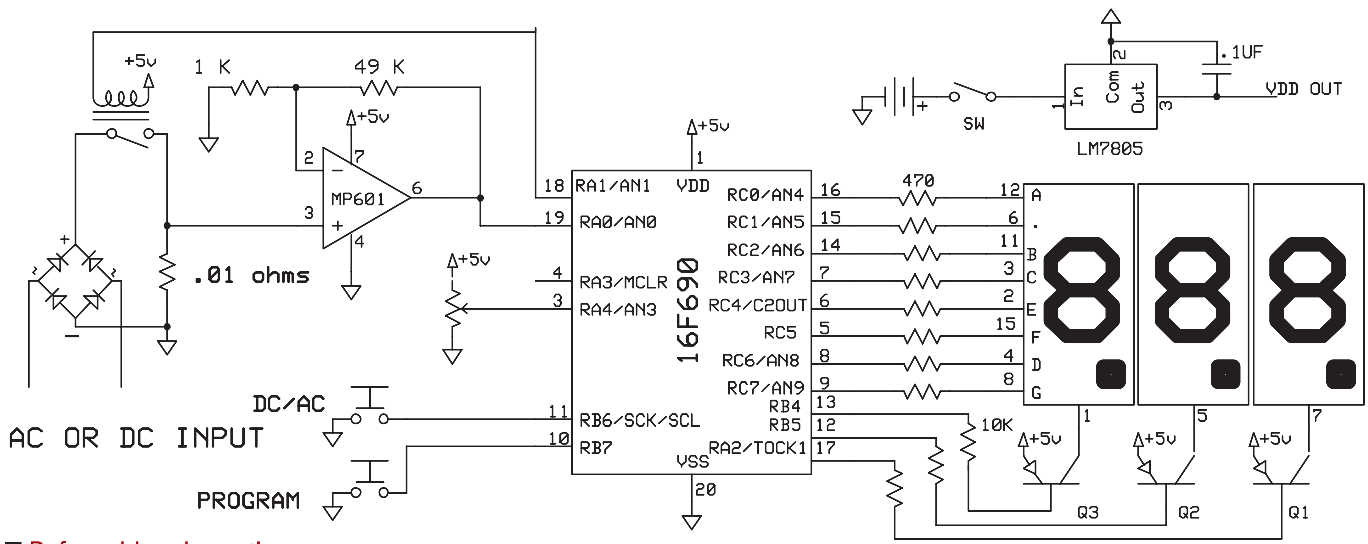
A .01 ohm 1% tolerance current sense resistor is used to provide the voltage drop to be measured. The drop-out relay is placed in series with the current sensing resistor. The voltage across the sense resistor is then amplified by a non-inverting op-amp with a gain of 50. It is then sampled through the micro's A/D. The offset voltage is corrected by subtracting it out in the software.

Boards, templates, the ASM and hex files can be found on the *Nuts & Volts* website at **www.nutsvolts.com**.

Building the Unit

The top side of the board has the printed components and the name of the board is on the bottom. Solder all the components to the board with the exception of the relay and the header. The battery wires go through the hole on the bottom to act as a strain relief. (Make sure to put the


■The Refuseable Box.



■ Refuseable schematic.

battery holder in its compartment first.) The current resistor goes between the heavy traces on the top side.

Enclosure

The enclosure is drilled using a template. The rectangle can be cut with a Moto tool, or drilled and filed. The red lens is then cemented on the top side using super glue.

Solder two 1″ green wires to the bridge diode AC input. Solder a 2″ black wire to the minus terminal and a 2″ red wire to the plus terminal. Use shrink tubing to

REFUSEABLE BOX PARTS LIST

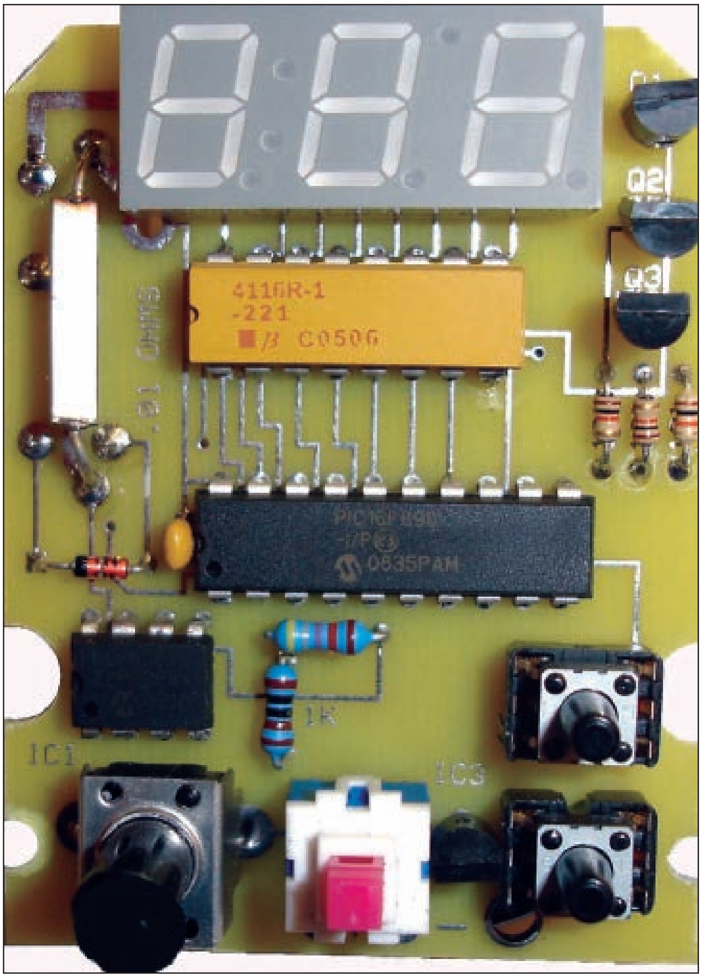
ITEM	QTY	DESCRIPTION
RESISTORS		
❑ R1	1	.01 1% Ohmite 610HR010E
❑ R2	1	1K 1% 1/6 watt
❑ R3	1	10K pot Panasonic - ECG EVU-F2AF30B14
❑ R4-R6	3	10K 1/6 watt
❑ R7	1	49K 1% 1/6 watt
❑ R8-R15	1	470 ohm eight DIP
CAPACITOR		
❑ C1	1	.01 µF
SEMICONDUCTORS		
❑ IC1	1	Microchip MCP601
❑ IC2*	1	Microchip 16F690
❑ D1	1	1N4148
❑ Q1-Q3	3	2N3906
❑ VR	1	LM7805L
❑ Bridge Diode	1	400 volt, six amp
OPTO	1	Lite-On, Inc. LTC-4624JR
HARDWARE		
❑ Nine-Volt Battery	1	
❑ Nine-Volt Battery Clip	1	

ITEM	QTY	DESCRIPTION
❑ Banana Jack Black	2	
❑ Box	1	Serpac 211
❑ Lens	1	PDR Plastics 6201030
❑ Relay	1	Tyco Electronics T77S1D10-05
❑ Screws #4 3/8″ Self-Tapping	2	
❑ Socket six-pin	2	
❑ Switch NO 9.5 MM	1	Panasonic-ECG EVQ-PAGO9K
❑ On/off Switch	1	PVA1 EE H1
❑ Wire 2" #20 Stranded	4	
❑ Board*	1	
❑ Header	6	

* A pre-programmed chip for $10.00 + shipping or a printed circuit board is available for $20.00 + shipping from:

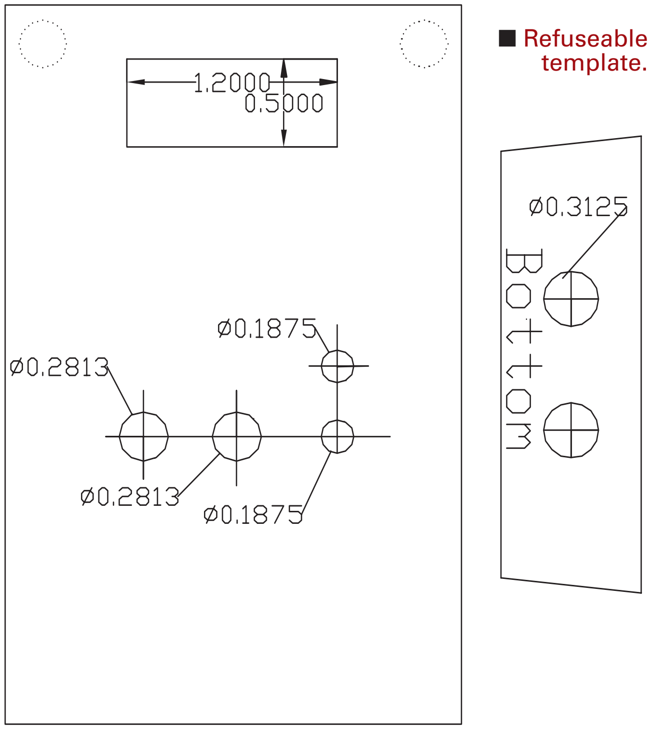
Ron Newton
2230 Damon Rd
Carson City, NV 89701
sjnewt@att.net
775-560-8842

A second Parts List with Digi-Key part numbers is available on the NV website.



■ Refuseable circuit board.

insulate the solder joint. Glue or screw-mount the diode to the bottom of the box. Solder the two green wires to the jacks. Solder the black wire to the – hole on the board and the red wire to the + hole on the board.



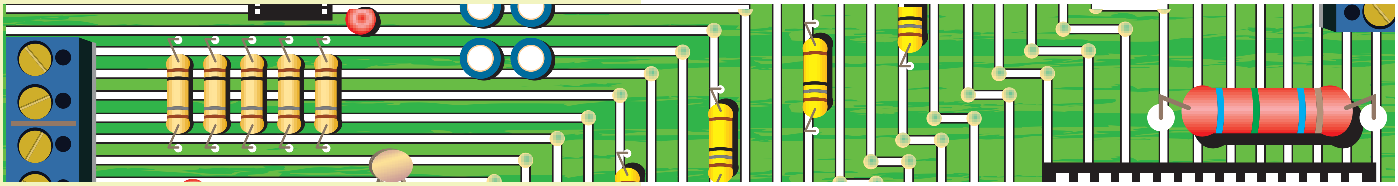
■ Refuseable template.

Once the enclosure is prepared, the board can be slipped into the top side of the enclosure and mounted using two #4 3/8" self tapping screws.

Using

Turn the unit on, hold down the program button, and adjust the pot until the desired amperage is observed. Switch from AC to DC using the other switch.

And remember, happy are those who just RE-FUSE! **NV**



Properly Selecting Electronic Components

Part 3

by Vaughn D. Martin

Parts 1 and 2 covered passive components. These last two parts examine active components. This part begins by investigating basic solid-state theory, diodes, rectifiers, transistor amplifiers, and characterizing them. Part 4 concludes the series with JFET and MOSFET transistors, and thyristors (to be explained).

Semiconductors are not truly conductors nor are they pure insulators. They are somewhere in between, residing in the Periodic Table's middle columns. Compared with metals, semiconductors are moderately good insulators, but nothing resembling true insulators like glass. A useful *intrinsic semiconductor* must have no more than one impurity atom in 10 billion. This is like a grain of salt

> An intrinsic semiconductor — or I-type semiconductor — is a pure semiconductor without any significant dopant present.

in a boxcar of sugar. Impure semiconductors are considerably more conductive. That is why semiconductor manufacturers intentionally add dopants.

> **Doping** is the process of adding controlled impurities to a semiconductor.

Dopants depend on the atomic properties of both the dopant and the material it affects. Generally, dopants producing the desired effects are either electron acceptors

> In 1869, the Russian chemist Dmitri Mendeleev conceived of the Periodic Table of elements. His design successfully accomplished its intent: to illustrate the recurring "periodic" trends of the elements. Elements occur by increasing atomic numbers, i.e., the number of protons in the atomic nucleus. Rows are arranged so that elements with similar properties fall into the same vertical columns. As stated, semiconductors occupy the middle three columns and have an equal number of valence or outer shell electrons to either dispense or capture.

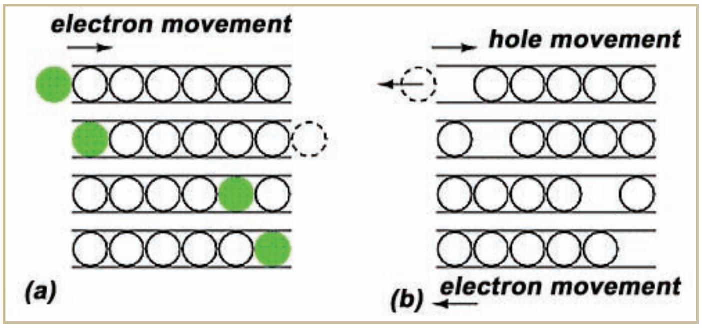


Figure 1. Marble in a tube analogy: (a) Electrons move right in the conduction band as electrons enter the tube. (b) Hole moves right in the valence band as electrons move left.

or donors. A donor atom that activates (becomes incorporated into the crystal lattice) donates weakly-bound valence electrons to the material. This creates an excess of negatively charged carriers. These weakly-bound electrons can move relatively freely in the crystal lattice, facilitating conduction within an electric field.

The donor atoms introduce some states below, but near the conduction band edge. You can easily excite electrons at these states to the conduction band, becoming free electrons. Conversely, an activated acceptor produces a hole. Semiconductors doped with donor impurities are ***N**-type*, while those doped with acceptor impurities are ***P**-type* materials. The **N** and **P** type designations indicate which charge carrier acts as the material's majority carrier. The opposite carrier is the minority carrier. This exists due to thermal excitation at much lower concentrations compared to majority carriers.

The Hole vs. Electron Controversy

Some people mistakenly believe that electron flow is current flow. Holes are where electrons previously resided. **Figure 1** shows an illustrative explanation using a marble analogy.

Electron flow in an N-type semiconductor is similar to electrons moving in a metallic wire. The N-type dopant atoms yield electrons available for conduction. These electrons are *majority carriers*, due to the dopent, and are in the majority compared to the very few thermal holes. If you apply an electric field across the N-type semiconductor bar, electrons enter the negative (left) end of the bar, traverse the crystal lattice, and exit to the (+) battery terminal (see **Figure 2a**).

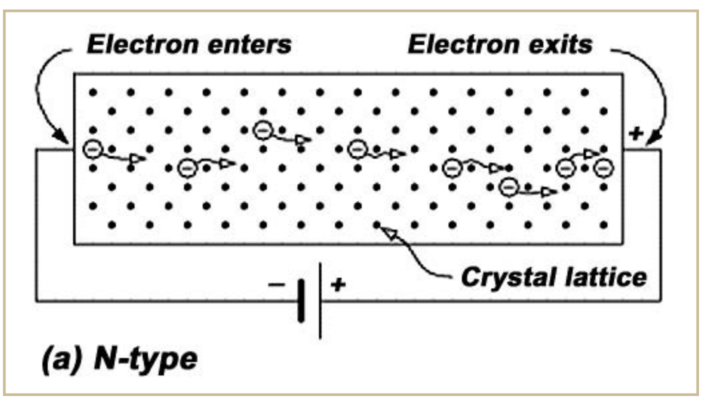
Diodes

A diode schematic symbol (**Figure 3b**) corresponds to the doped semiconductor bar at **Figure 3a**. The diode is a *unidirectional* device. Electron current only flows in one direction: against the arrow, corresponding to forward bias. The cathode (bar) of the diode symbol corresponds to the N-type semiconductor. The anode (arrow) corresponds to the P-type semiconductor. To remember this relationship, think of **N**ot-pointing (bar) on the symbol corresponds to **N**-type semiconductors. **P**ointing (arrow) corresponds to **P**-types.

An early diode application was as a radio frequency detector that recovered audio from a radio signal. This polycrystalline was a piece of the mineral galena (lead sulfide). A pointed metallic wire (cat whisker) touched a spot on a crystal within the polycrystalline mineral (see **Figure 4**). You struggled to find a "sensitive" spot on the galena. Presumably, there were P and N type spots randomly distributed throughout the crystal due to the variability of uncontrolled impurities. Another detector — part of a foxhole radio — used a pencil lead bound to a bent safety pin, touching a rusty disposable razor blade. These all required searching for a sensitive spot; easily lost because of vibration.

The Diode Advances and Evolves

Replacing the mineral with an N-doped semiconductor made the whole surface sensitive,



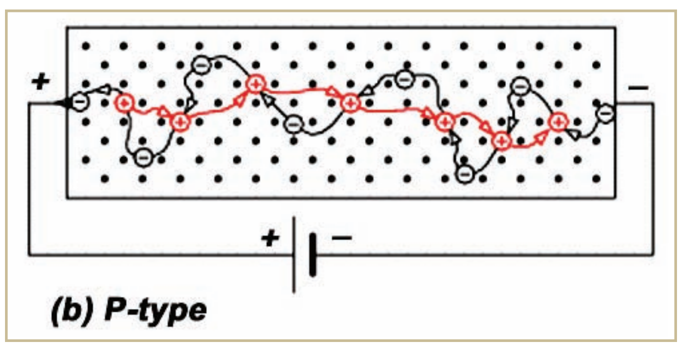


Figure 2. (a) N-type semiconductor with electrons moving left to right through the crystal lattice. (b) P-semiconductor with holes moving left to right which corresponds to electrons moving in the opposite direction.

and conquered the sensitive spot searching problem (see **Figure 5a**). G.W. Pickard perfected this device in 1906. The pointed metal contact produced a localized P-type region within the semiconductor. The metal point was fixed in place, and the whole point contact diode was encapsulated in a cylindrical body for mechanical and electrical stability (see **Figure 5d**). Note that the cathode bar on the schematic corresponds to the bar on the physical package. The point contact diode preceded the junction diode and modern semiconductors by several decades. It may seem primitive to you; however, this diode has such low capacitance it makes an excellent microwave frequency detector. Although they are sensitive to a wide bandwidth, their downfall though is they have a low current capability compared with junction diodes.

Most diodes today are silicon junction (see Figure 5b). They look more complex than a simple PN junction. Starting at the cathode connection, the N^+ indicates this region is heavily doped which has nothing to do with polarity. This reduces the series resistance of the diode. The N^- region is lightly doped as indicated by the (-). Light doping produces a diode with a higher reverse breakdown voltage — important for high voltage power rectifier diodes. Lower voltage diodes — even low voltage power rectifiers — would have lower forward losses with heavier doping.

The heaviest level of doping produces zener diodes designed for a low reverse breakdown voltage. However, heavy doping increases the reverse leakage current. The P^+ region at the anode contact is a heavily doped P-type semiconductor — a good contact strategy. Glass encapsulated small signal junction diodes are capable of 10s to 100s of mA of current. Plastic or ceramic encapsulated power rectifier diodes handle up to 1,000s of amperes of current.

Zener diodes are silicon reversed biased semiconductors used as a voltage regulator because of their ability to maintain an almost constant voltage over wide current ranges.

Bridging the Gap from Diode to Transistor

The bipolar junction transistor (see **Figure 6a**) is an NPN, three-layer semiconductor sandwich with an emitter and collector at the ends, and a base in between. It is as if a third layer were added to a two-layer diode. If this were the only requirement, we would have no more than a pair of back-to-back diodes. (In fact, it is far easier to build a pair of back-to-back diodes.) The key to the fabrication of a bipolar junction transistor is to make the middle layer (the base) as thin as possible.

Bipolar Transistors

This three-layer device has two semiconductor diode

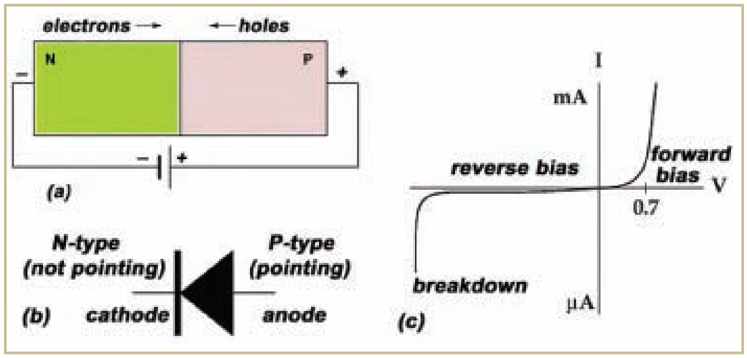


Figure 3. (a) P-N junction; (b) corresponding diode schematic symbol; and (c) silicon diode I vs. V characteristic curve.

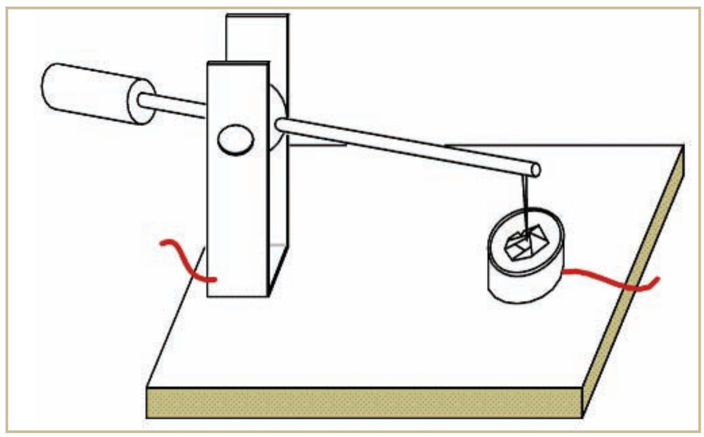


Figure 4. A crystal detector used as a crude elementary radio receiver.

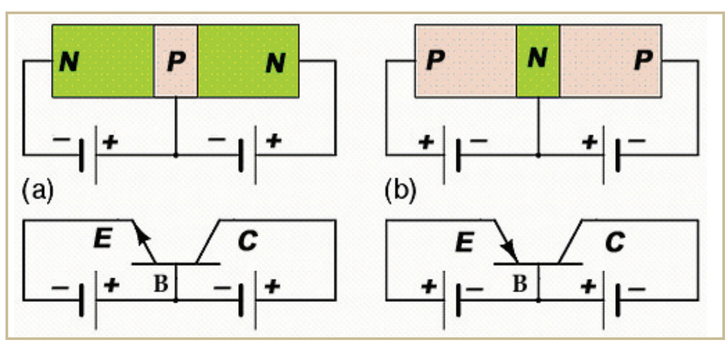


Figure 5. Silicon diode cross-section: (a) point contact diode; (b) junction diode; (c) schematic symbol; and (d) small signal diode package.

junctions joined together: one forward biased and one reverse biased (see **Figures** 7 and **8**). Transistors are current operated devices where a much smaller base current causes a larger emitter-to-collector current to flow. These currents are nearly equal; look at **Formula 1**.

$\beta = I_C / I_B$ and $I_E = I_B + I_C$ Formula 1

The word transistor is an acronym and combination of the words **trans**fer res**istor** used to describe their mode of operation, which began in their earliest development.

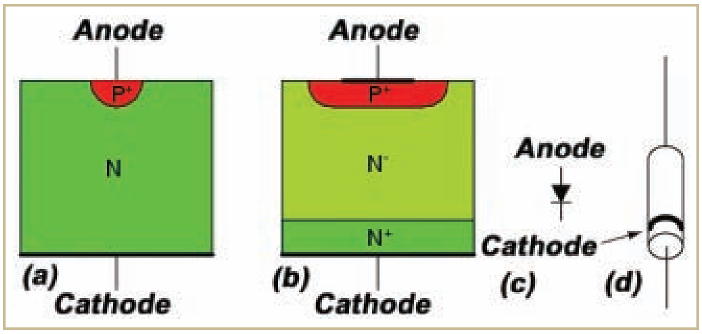


Figure 6. Comparing an NPN transistor at (a) with the PNP transistor at (b). Note direction of emitter arrow and supply polarity.

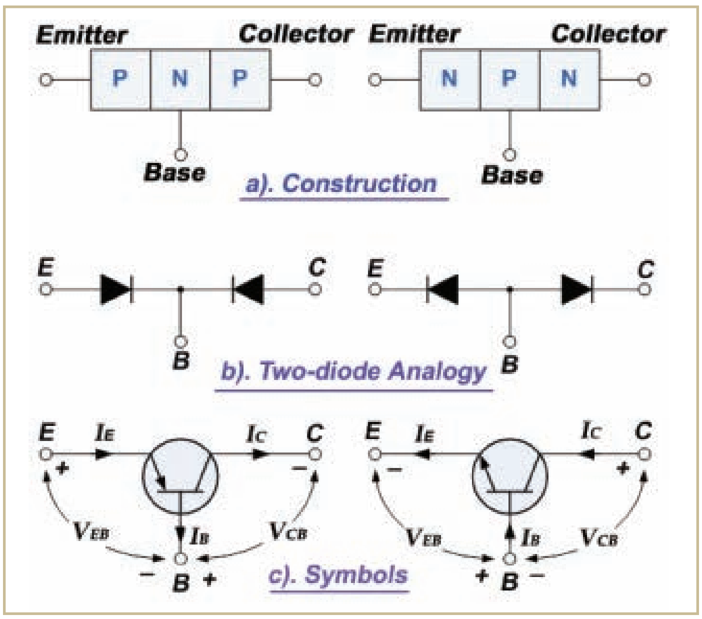


Figure 7. (a) The construction and circuit symbols for both the NPN and PNP transistors; the arrow in the circuit symbol always shows the direction of conventional current flow between the base terminal and its emitter terminal; (b) a two diode analogy; and (c) the direction of the arrow pointing from the positive P-type region to the negative N-type region — exactly the same as for the standard diode symbol.

You reverse bias the base-collector junction of a bipolar junction transistor again (see Figure 7c). This increases the width of the depletion region. The reverse bias voltage could be a few volts to tens of volts for most transistors. There is no current flow except leakage current in the collector circuit.

You need to add a voltage source to the emitter-base circuit. Normally, you forward bias the emitter-base junction, overcoming the 0.6V potential barrier. This is similar to forward biasing a junction diode. This voltage source needs to exceed 0.6V for majority carriers (electrons for NPN) to flow from the emitter into the base, becoming minority carriers in the P-type semiconductor.

If the base region was thick — as in a pair of back-to-back diodes — all the current entering the base would flow out the base lead. In our NPN transistor example, electrons leaving the emitter for the base would combine with holes in the base, making room for more holes to evolve at the (+) battery terminal on the base as electrons exit.

Since the base is so thin, a few majority carriers in the emitter injected as minority carriers into the base actually recombine (see Figure 8). Few electrons injected by the emitter into the base of an NPN transistor fall into holes. Also, few electrons entering the base flow directly through the base to the positive battery terminal. Most emitter electrons diffuse through the thin base into the collector. Modulating the small base current produces large collector current changes. If the base voltage falls below approximately 0.6V, the large emitter-collector current ceases to flow.

The thin base and the heavily doped emitter help keep the emitter efficiency high; 99% is typical. The 100% emitter current splits between the base as 1% and the collector as 99%. The emitter efficiency is alpha $\alpha = I_C / I_E$ and can only approach (but never reach) 1.00. The higher the gain or beta, β, the closer alpha approaches 1.00; see the last illustration in Figure 8.

Transistor Configurations

The most common transistor connection is the common emitter configuration (see **Figure 9**). The collector or output characteristics curves can be used to find either I_B, I_C or β to which a load line can be constructed to determine a suitable operating point, Q, with variations in base current determining the operating range. A transistor can also be used as an electronic switch to control devices such as lamps, motors, and solenoids. Inductive loads such as DC motors, relays and solenoids require a reverse biased "flywheel" diode placed across the load. This helps prevent any induced back EMFs generated when the load is switched "OFF" from damaging the transistor. Part 2 discussed this flyback,

kickback, or flywheel effect. The NPN transistor requires the base to be more positive than the emitter while the PNP type requires that the emitter is more positive than the base.

Induced EMF (electromotive force) generates a voltage by changing the magnetic field that passes through a coil of wire.

The Common Emitter Configuration

This is the most common of the three transistor configurations (see **Figure 10**). An application that proves particularly useful is using a transistor as a switch. It switches all the way on and then all the way off (see **Figure 11**). Note that at full on, it is saturated and fully off it is at cut-off. This is the basis of digital electronics because at fully ON it is a logic one and at fully OFF it is a logic zero.

Amplifying AC Signals

One common emitter amplifier configuration is a Class A amplifier. This is one when you bias the base so that the transistor is always operating halfway between its cut-off and saturation points. This allows the transistor amplifier to accurately reproduce the positive and negative halves of the AC input signal superimposed upon the DC biasing voltage. Without this "bias voltage," only the positive half of the input waveform would be amplified; this cuts off the bottom half of the AC.

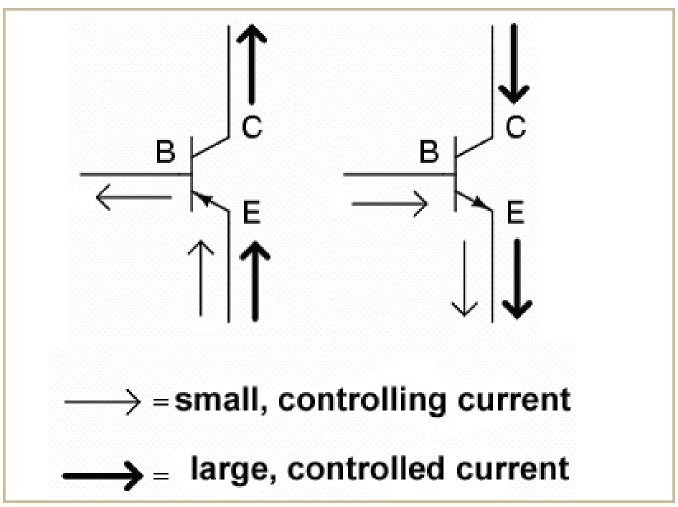


Figure 11. A Class A NPN transistor amplifier operating with the base biased to allow operating halfway between its cut-off and saturation points.

Note that the I_C is largely unaffected by changes in V_{CE} above one volt and is almost entirely controlled by the base current, I_B. When this happens, you can say that the output circuit is a "constant current source." Note from

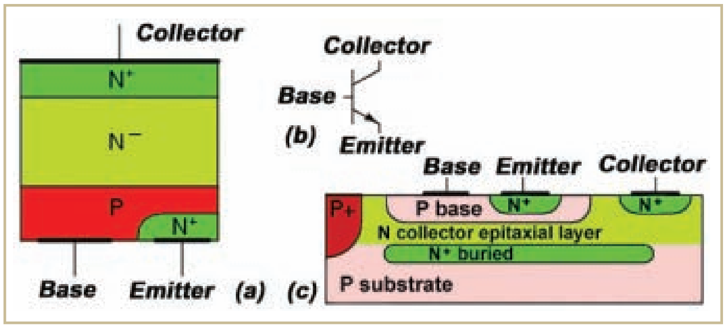


Figure 8. Bipolar junction transistor: (a) discrete device cross-section; (b) schematic symbol; and (c) integrated circuit cross-section.

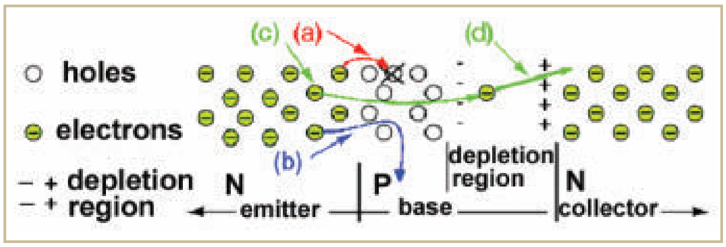


Figure 9. Disposition of electrons entering base: (a) loss due to recombination with base holes; (b) flow out base lead; (c) most diffuse from emitter through thin base into base-collector depletion region; and (d) are rapidly swept by the strong depletion region electric field into the collector.

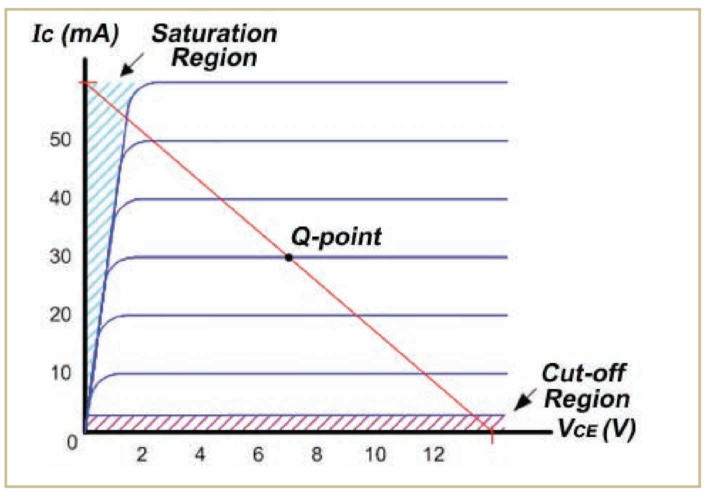


Figure 10. The pink shaded area at the bottom represents the "cut-off" region. Here the operating conditions of the transistor are zero input base current (I_B), zero output collector current (I_C), and maximum collector voltage (V_{CE}). The lighter blue area to the left represents the "saturation" region.

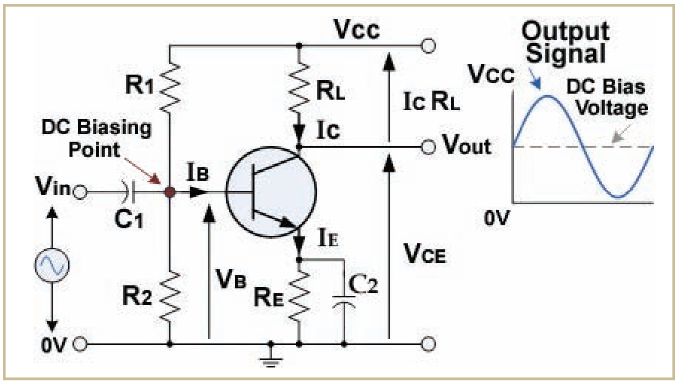


Figure 12. Output characteristic curves for a typical bipolar transistor. Note the effect of V_{CE} upon the collector current I_C when V_{CE} is greater than about 1.0 volts.

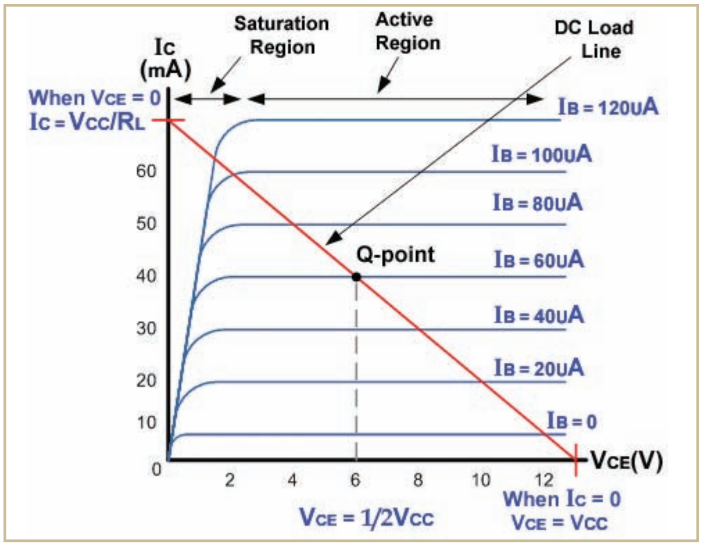


Figure 13. Since we've learned that transistors are basically two diodes connected together, you can use this analogy to determine a transistor's polarity. That is whether it is a PNP or NPN by testing the resistance between its three different leads; also see **Table 1**.

Resistance Between Transistor Terminals

		PNP	NPN	
Collector		Emitter	R_{high}	R_{high}
Collector		Base	R_{low}	R_{high}
Emitter	Collector	R_{high}	R_{high}	
Emitter	Base	R_{low}	R_{high}	
Base	Collector	R_{high}	R_{low}	
Base	Emitter	R_{high}	R_{low}	

Table 1. The resistance between transistor terminals that can tell you what pin has what function based on the fact that a transistor is composed of two diodes placed back-to-back.

the common emitter circuit that the emitter current, IE, is the sum of the collector current, I_C, and the base current, I_B, added together. So, we can also say that "$I_E = I_C + I_B$" for the common emitter configuration, as previously mentioned.

The Need for Greater Amplification

Thus far, our transistor example had a gain of 100. Can you imagine maybe requiring another 100 times that much additional gain? You need this when the input is a small sensor such as a solar cell (see **Figures 14** and **15**); a thermocouple (see **Figure 16**); or maybe a faint sound from a tuning fork activating a small microphone (see **Figure 17**).

Note in Figure 17 that there are four diodes constituting a bridge.

This ensures that both positive and negative signals are routed to the transistor amplifier. The small light has resistance and it substitutes for the collector-resistor normally found there.

To provide this extra gain, you can place transistor stages back to back and realize almost a 100 squared gain; assuming both transistors have a β of 100. This arrangement is a Darlington pair (see **Figure 18**).

Figure 14. A solar cell driving a light.

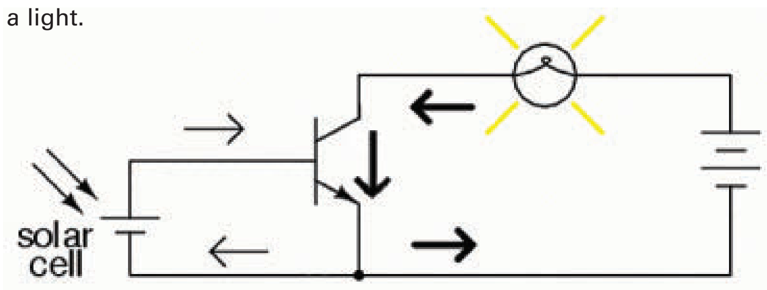
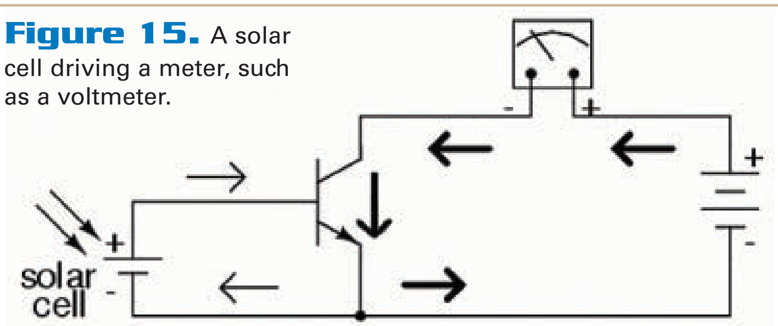


Figure 15. A solar cell driving a meter, such as a voltmeter.



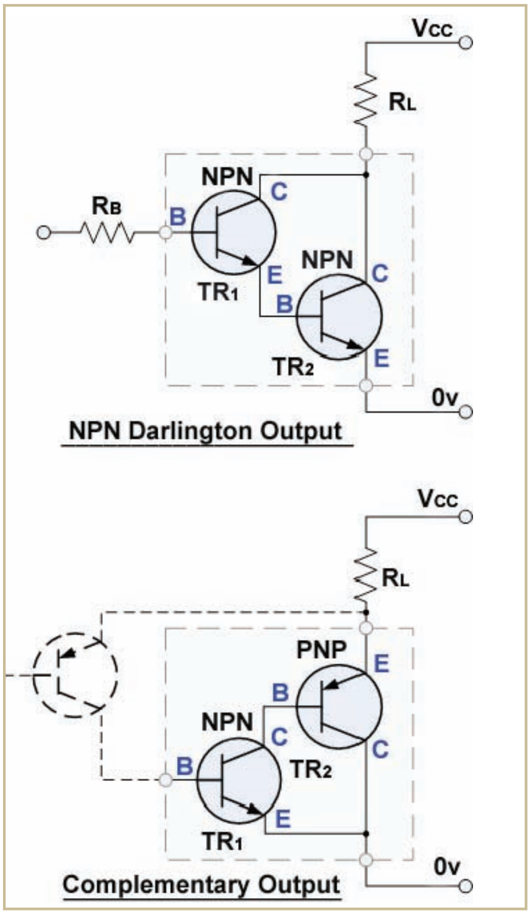


Figure 18. An NPN Darlington transistor configuration with collectors of the two transistors connected together. The first "input" transistor receives an input signal, amplifies it, and uses it to drive the second or "output" transistor. Another advantage of a Darlington is its high switching speeds that make them ideal in DC motor or stepper motor control applications.

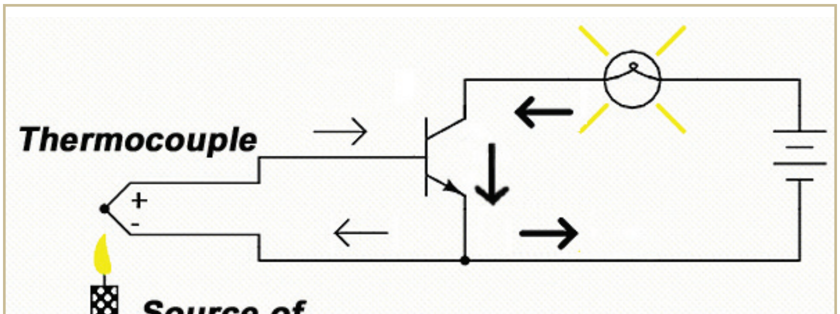


Figure 16. A heat source creating a thermal gradient across joined dissimilar metals (thermocouples).

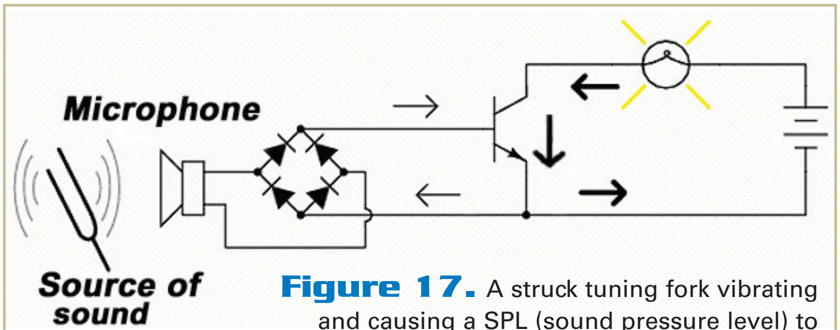


Figure 17. A struck tuning fork vibrating and causing a SPL (sound pressure level) to develop across the microphone that applies this to the transistor amplifier.

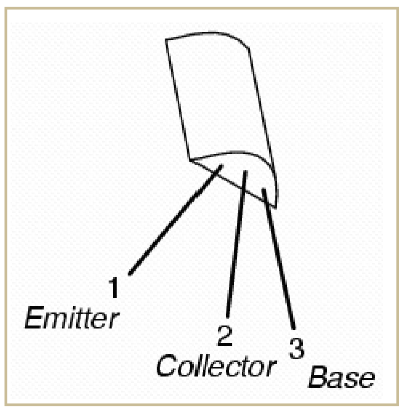


Figure 19. Using two DMMs' resistance scale to determine the polarity and to identify which lead is what on a PNP transistor.

In 1821, the German–Estonian physicist Thomas Johann Seebeck discovered that when you join and subject any metal pairs to a thermal gradient, they generate a small voltage. This is the thermoelectric or Seebeck effect. These joined metal pairs are **thermocouples**.

Identifying Diodes and Transistors

Since we've seen that transistors are basically two diodes connected together, you can use this analogy to determine a transistor's polarity (if it is a PNP or NPN) by testing resistance between its three leads. Use **Table 1** in addition to the meter for this task. **Figure 19** shows how you can determine if it is a PNP transistor using a DMM on the resistance scale. **Figure 20** shows how to determine a transistor's polarity using a DMM. Table 1 summarizes this for transistors.

You also can use a DMM's resistance scale and determine a diode's orientation (see **Figure 21**). **Figure 22** shows how you can accomplish this same task by using a six volt battery.

1. Emitter-Base Terminals: The emitter to base should act like a normal diode and conduct one way only.

2. Collector-Base Terminals: The collector-base junction should act like a normal diode and conduct one way only.

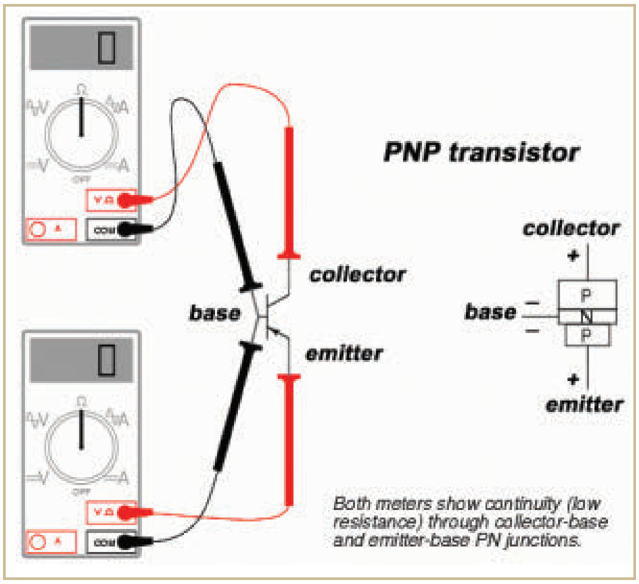
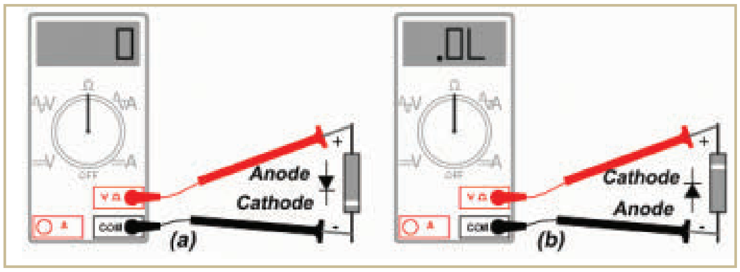
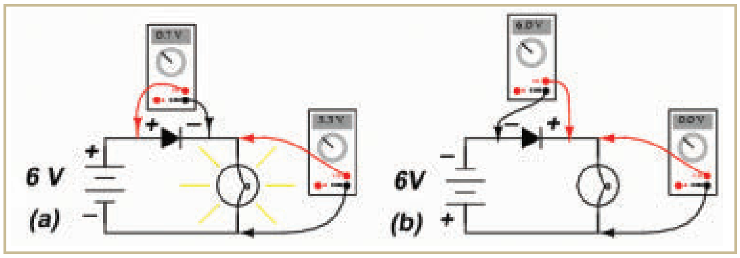


Figure 20. Using a DMM resistance scale to determine the anode from the cathode of a diode.





Figures 21 and 22. Using a DMM's voltage scale and six volt battery to determine a diode's cathode and anode.

3. Emitter-Collector Terminals: The emitter-collector should not conduct in either direction.

Tune in next month for our wrap up on active components. **NV**

Experiments with Alternative Energy

Part 2 - External Conditions that Affect Solar Panels

By John Gavlik, WA6ZOK

This is the second in our series of Experiments with Alternative Energy. In Part 1, you were introduced to how a Parallax BS2 and PICAXE 28X2 can be configured in hardware and firmware to measure certain electrical aspects of solar panels; namely what their voltage, current, and power outputs look like in both sun and incandescent light and the concept of the Maximum Power Point or MPP. This time, we'll use these same microcontroller circuits and code to illustrate three primary conditions that affect solar panel operation in the real world: heat, shading, and tilt angle.

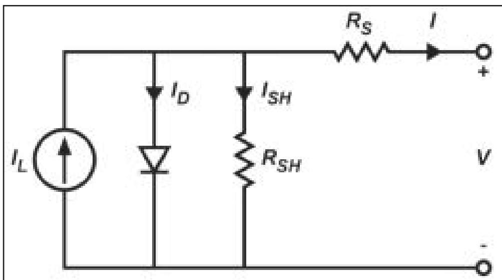


Figure 1 – Solar Cell Equivalent Circuit.

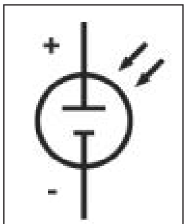


Figure 2 – Solar Cell Symbol.

The three experiments that complement this article can be viewed in their entirety and downloaded from the Experimenter Kits section of the LearnOnline website or the Media Downloads section of *Nuts & Volts*.
www.learnonline.com
www.nutsvolts.com

If you ever considered installing solar panels on your home or business, this article will have some meaning for you. That said, this is not an article on solar panel installation. Rather, it delves into the reasons why solar panels behave as they do by way of some interesting experiments and how the concept of Maximum Power Point (MPP) — which is affected by all these conditions — is so important when solar panels are used on moving vehicles. For what follows, you will need the background from Part 1, so refer back to your August *NV* issue or visit the website for access to the digital archives (**www.nutsvolts.com**). Also, be sure to visit **www.learnonline.com** and click on Experimenter Kits for extended details on the experiments mentioned here and other alternative energy products.

Solar Cell Equivalent Circuit

As a preliminary step in illustrating how heat, shading, and tilt angle affect the performance of a solar panel, it will be useful to examine the inner-workings of a typical silicon solar cell in terms of an equivalent circuit; this is shown in **Figure 1**. This way, you can relate these issues to the same devices that you are accustomed to using in your other circuits. The equivalent circuit is embodied in the symbol for the solar cell in **Figure 2**.

An ideal solar cell may be modeled by a current source in parallel with a diode; however, in practice no solar cell is this perfect so a shunt resistance and a series resistance component are added to the model to simulate voltage and current losses. Photons excite the solar cell's

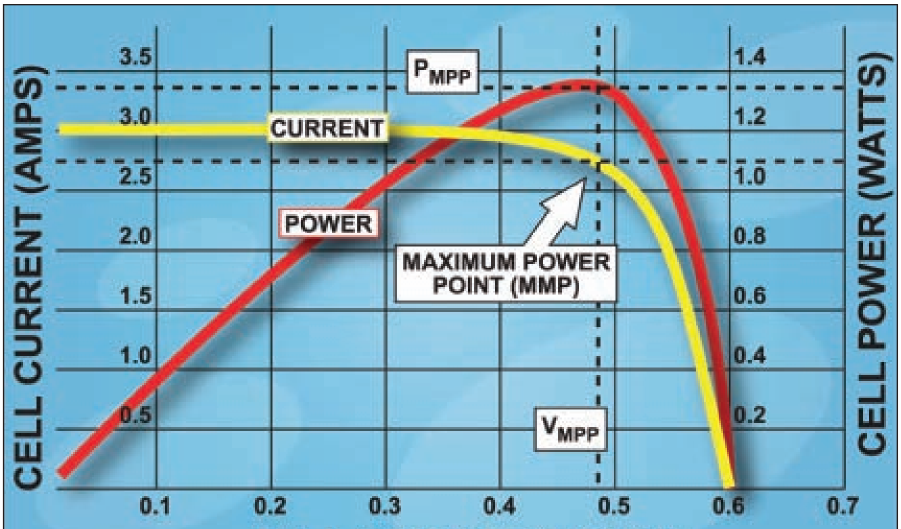


Figure 3 – IV Curve Plot Showing MPP.

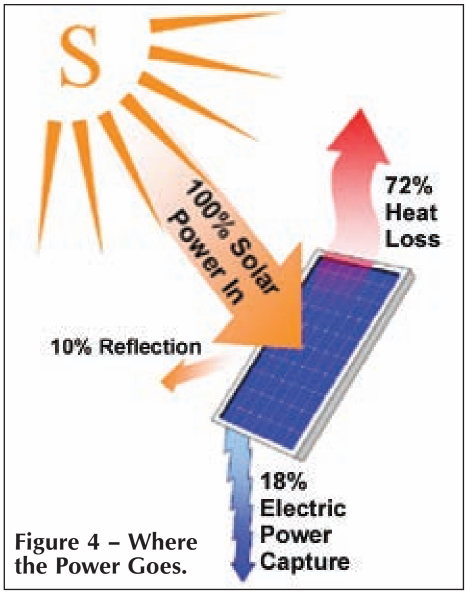


Figure 4 – Where the Power Goes.

material and produce voltage and current flow through the p-n junction by electron and hole movement. This process can be expressed as follows:

$$V_j = V + IR_S$$

where
V_j = Voltage across both diode and shunt resistor R_{SH}
V = Voltage across the output terminals (volts)
I = Output current (amperes)
R_S = Series resistance

I'm purposely leaving out a lot of math and physics here to keep the focus of the explanation in the realm of basic electrical concepts that we all understand. For example, when a typical carbon resistor gets hot its resistance increases and vice versa. Well, the same thing happens to the shunt and series resistors in the equivalent circuit. As they heat up, the output voltage decreases. However, the current stays mostly the same; you will see this as part of the experiment on heat. This cursory explanation should suffice to get acquainted with the basics of a typical silicon solar cell. You are, of course, encouraged to find out more to satisfy your level of curiosity and technical background. The Web is the place to go.

How Solar Panels Are Rated — Voc and Isc

If you look up the specs on any solar panel sold today, you will see that it is rated by open-circuit voltage (Voc) and short-circuit current (Isc). While the output power for either of these two extreme conditions is zero, the rating is an important issue in the choice of a solar panel because by using these two ratings, you can determine its overall power producing capacity. It brings the discussion back to what you were introduced to in Part 1: the MPP; that is, the load for which the cell can deliver maximum electrical power at a given level of sunlight. To illustrate the MPP, **Figure 3** is a plot of current versus voltage or what has commonly become known as an "IV curve." Voltage is plotted on the horizontal axis with current and power plotted on the vertical axis. The maximum power, then, is dependent on the size of the Voc at the very top-left of the plot and the Isc at the bottom-right. The MPP will exist somewhere in between, depending on the amount of sunlight, heat, and tilt angle.

The Effect of Heat

Let's start with one unavoidable condition: heat. Regardless of where you live in either a hot or cold climate, radiant heat will deteriorate a solar panel's performance (and even life) to some degree. Heat does two basic things. It affects the internal nature of the individual solar cells such that the cell cannot produce the same voltage and current when it was cooler. Heat also causes the resistance to increase in the wires that connect the solar cells together. The metal superstructures that hold the solar cells in place transfer their heat to the cells. The combination of these two factors reduces the overall current and voltage produced by the panel.

Figure 4 is a good illustration of where the power goes when a solar panel is exposed to sunlight. Some of it gets reflected off the surface and doesn't produce any power. The majority of the sunlight enters the panel and part of it (the photons at particular wavelengths — see "band gap" from Part 1) generates the actual voltage and current, depending on the type of material used for the solar cells. The rest of it gets converted into radiant heat that reduces the power output.

The cure for this condition is relatively simple: wind and/or cool temperatures. Just as a cool breeze can reduce your internal temperature, it can do the same for solar panels. And not so surprisingly, the power output improves when this happens. **Figures 5** and **6** are taken

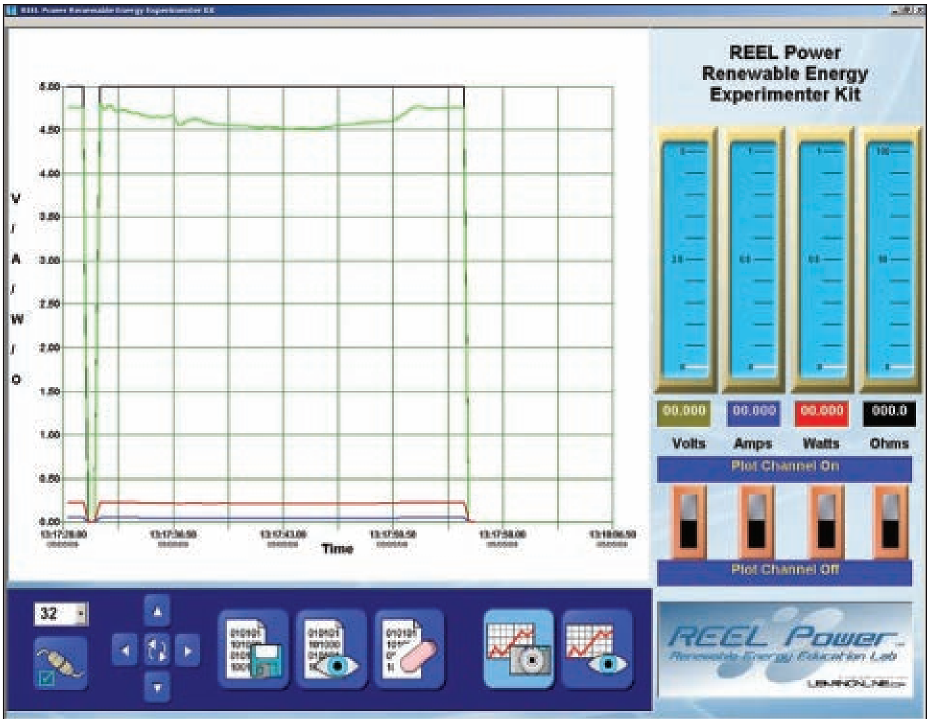


Figure 5 – Plot of Solar Panel Output Based on Heating and Cooling.

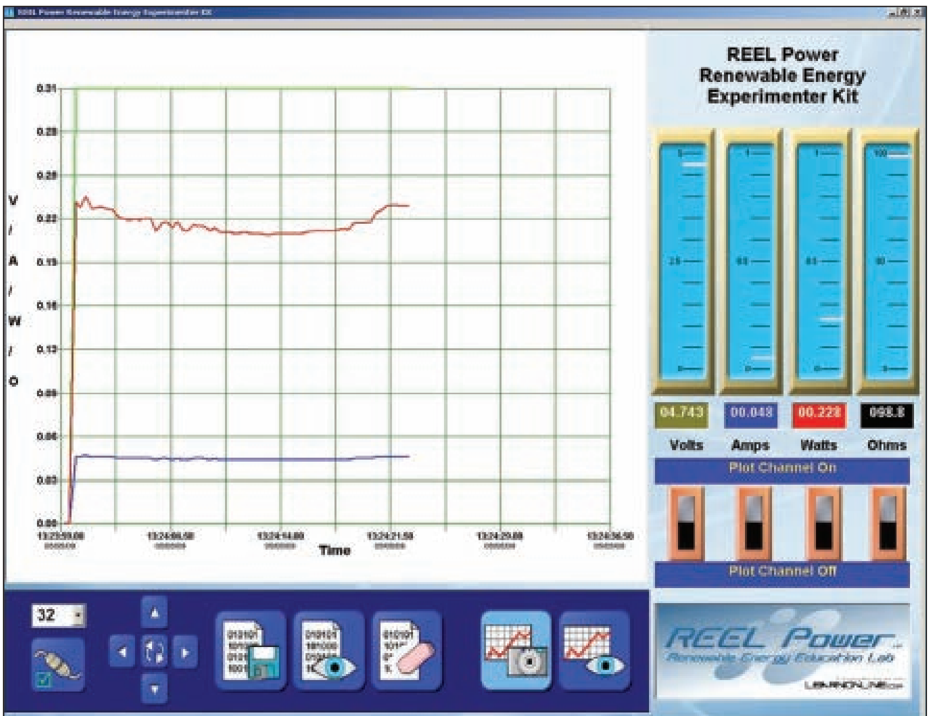


Figure 6 — Expanded View of Power (red) and Current (blue).

from the experiment entitled "The Effects of Heat on a Solar Panel." They show what happens to the voltage, current, power, and resistance (your BS2 and 28X2 circuits and code measure resistance, too) as the solar panel gets hot and then cools off. As the heat increases, the voltage decreases but the current remains reasonably constant; the same is true during the cooling cycle except the voltage increases proportionally with the panel temperature. The heating and cooling also shifts the MPP somewhere else on the IV curve. I'll address this shortly.

The Effect of Shading

Unlike heat, shading is something that can — and should be — avoided because it is potentially more damaging to the solar panel than external heat itself. Since a solar panel is constructed of individual solar cells wired in series-parallel arrangements, if an individual solar cell or small cluster of them is shaded, the shaded cells essentially shut off current flow through the rest of the circuit. This is kind of like a string of holiday lights where if one burns out, the rest quit operating; that one burned-out light bulb broke the circuit to the rest of the string. If solar panels operated like this, it might not be such a big issue; however unlike a string of light bulbs, the individual solar cells are all mini current and voltage generators that are looking for a place to deliver their power. A shaded cell blocks the current flow and causes the other illuminated cells to get hot trying to dissipate their power into a high resistance path created by the shaded cells.

Shading is caused by both natural and manmade obstructions. Clouds don't normally cause harm because they shade the entire panel; however, snow, trees, and buildings can partially shade small areas of a panel long enough for permanent damage to occur. Some solar panels have blocking diodes to prevent this, but the cost for this is lower voltage output due to the diode drop itself.

One way around this condition is to configure solar panels in parallel rather than in series. This does not completely eliminate damage to the solar panel by the shaded cells but it does mitigate the overall performance of the entire system. For example, **Figure 7** illustrates what happens with two identical solar panels in series. Partially shading just a portion of one panel dramatically reduces the voltage and power output of the pair. On the other hand, **Figure 8** shows the same panels in parallel. Shading the

same amount of panel area does not affect the power output nearly as drastically, since some of the illuminated solar cells have somewhere to deliver their voltage and current. *You can perform this experiment yourself by going to "The Effects of Shade on Solar Panels" on the LearnOnLine website. (Just click on the Experiment Kit menu link.)*

The Effect of Tilt Angle

It is fundamentally obvious that the best angle for a solar panel is one that points it directly in line with the light source. While this is indeed the case, most solar panels cannot be oriented directly toward the light source at all times. Since the sun [appears] to move across the sky during the day, a solar panel can only gather a portion of its light depending on its fixed tilt angle. So, there is a compromise to consider here; what angle is best for the given solar panel's application? Most applications for solar panels are on roof tops where the solar panel is mounted in a fixed position. **Figure 9** illustrates the sun's angle at its lowest and highest points during the year at the Winter and Summer Solstice, respectively, so the panel should be mounted somewhere between these two angles. One more consideration comes into play and that's your geographical location or — in particular — your latitude. Based on the latitude, your panel should be mounted plus or minus 15 degrees from it as illustrated in **Figure 10**.

What happens to the solar panel's voltage, current, and power outputs under load at various tilt angles can be determined by examining **Figure 11**. As expected, a fixed solar panel's electrical parameters react generally like this illustration. *You can see for yourself by performing the "Effects of Tilt Angles on Solar Panels" experiment.*

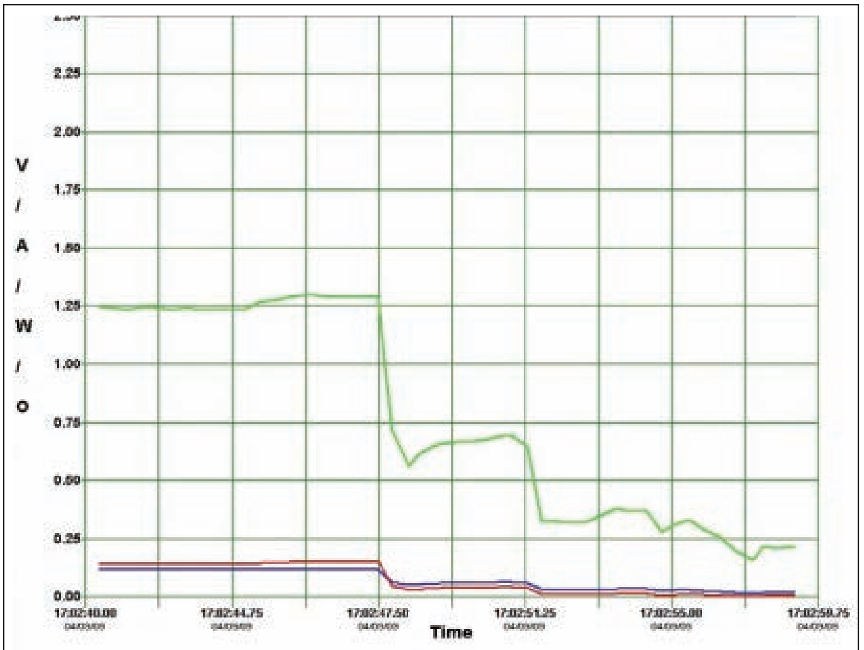


Figure 7 – Shade on Solar Panels in Series.

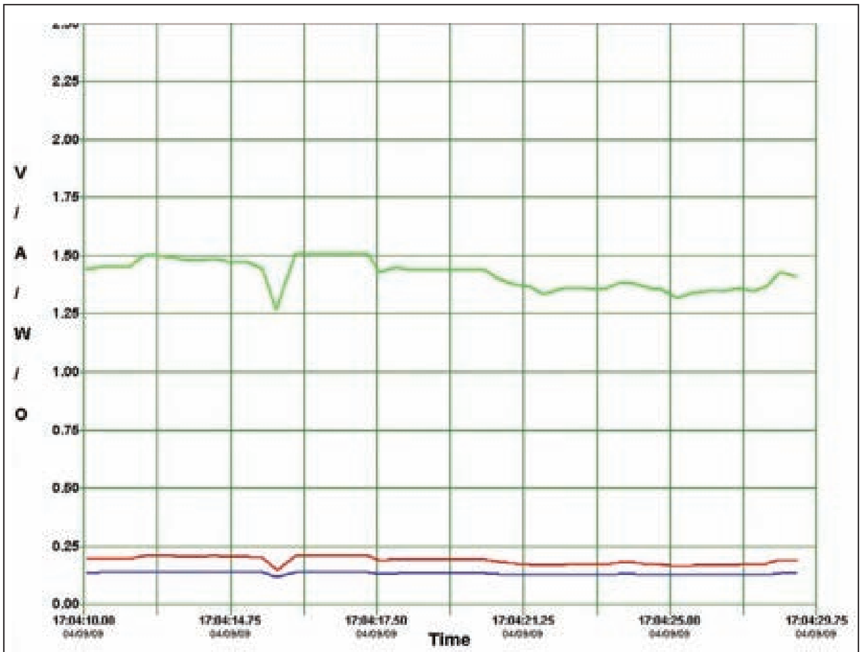
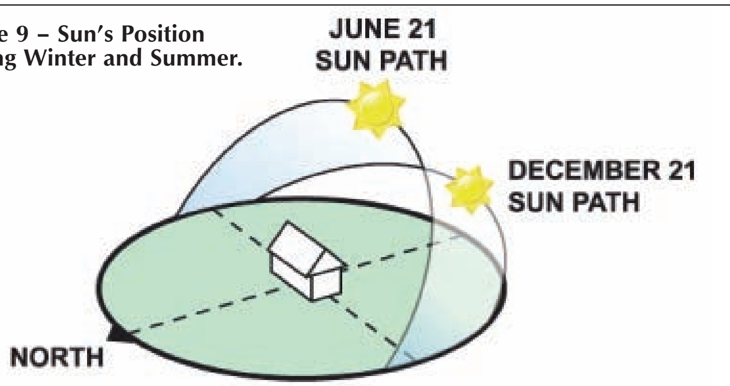


Figure 8 – Shade on Solar Panels in Parallel.

Figure 9 – Sun's Position During Winter and Summer.



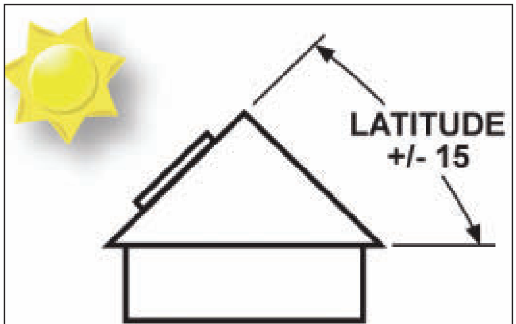


Figure 10 – Computing the Best Tilt Angle.

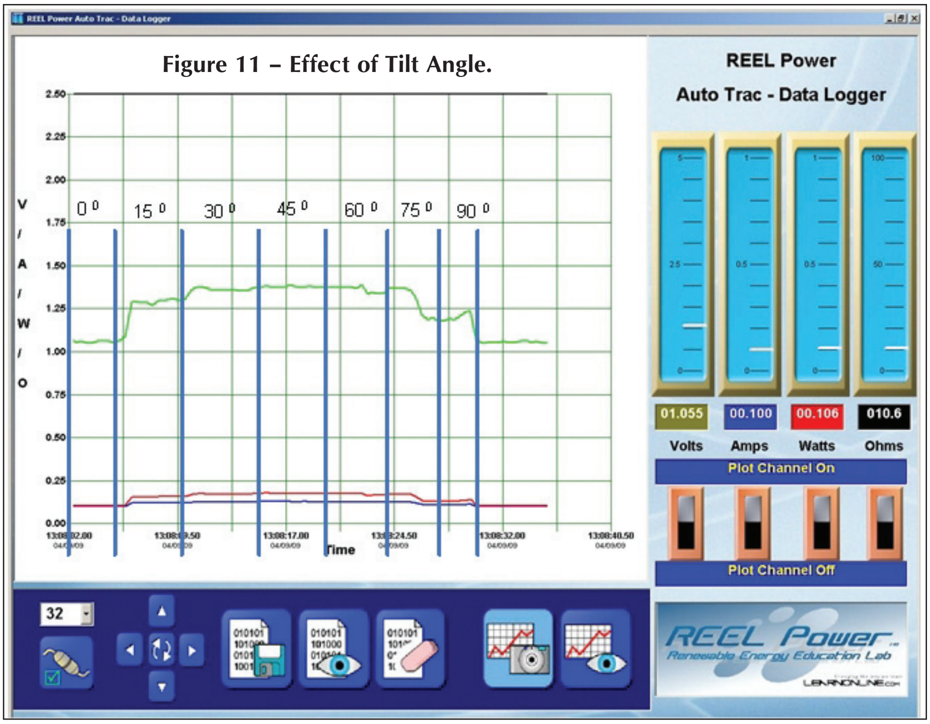


Figure 11 – Effect of Tilt Angle.

A modern solar race car is made up of more than just an electric motor connected to solar panels with an ON-OFF switch in between. How would you ever get anywhere with the varying angles of light striking the fixed solar panels on the car's body? There are some very sophisticated electronics that go along this to regulate its speed, as well as its ability to acquire the maximum sun energy as it travels. One such device is called a Maximum Power Point Tracker or MPPT (one more acronym to deal with). An MPPT is really a DC-to-DC converter with some bells and whistles thrown in. What it doesn't do is mechanically track the sun as the car moves. What it DOES do is track the shift in MPP — thus the name. How it does this is quite interesting.

The MPPT controller sits between the solar panel and the car's battery as illustrated in **Figure 14**. As a high frequency DC-DC converter, it takes the DC input from the solar panels at whatever voltage they are at and digitally converts it to a high frequency AC signal. Then it converts it back down to a DC voltage and current to exactly match the battery's needs right at that particular moment — all under microprocessor control (which could be done with a BS2 or 28X2 programmed in BASIC with no major issues). With a micro doing the work, the connection between the panels and battery is actually "broken" for a few milliseconds during the normal operational cycle to "look" at the solar panel and battery independently to make needed adjustments. Refer to **Figure 15** for timing.

Modern MPPTs are around 92% to 97% efficient in

Tracking the Shift in MPP

Now we come to the culmination of the effects of heat, shading, and tilt angle: how these conditions shift the Maximum Power Point — especially in mobile applications.

To obtain the optimum performance from a solar panel, it is important to understand how it behaves in a mobile application where it moves quickly among relatively fixed light, heat, and shadow-producing sources. For a fixed solar panel, **Figures 12** and **13** show how just a solar panel's tilt shifts the MPP. Imagine what happens when we mount the same solar panels on a solar race car and put them in motion.

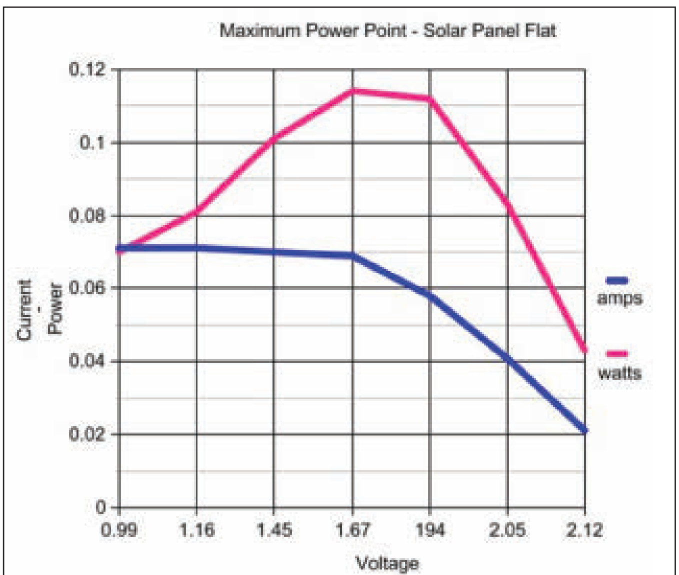


Figure 12 – MPP for Solar Panel Lying Flat.

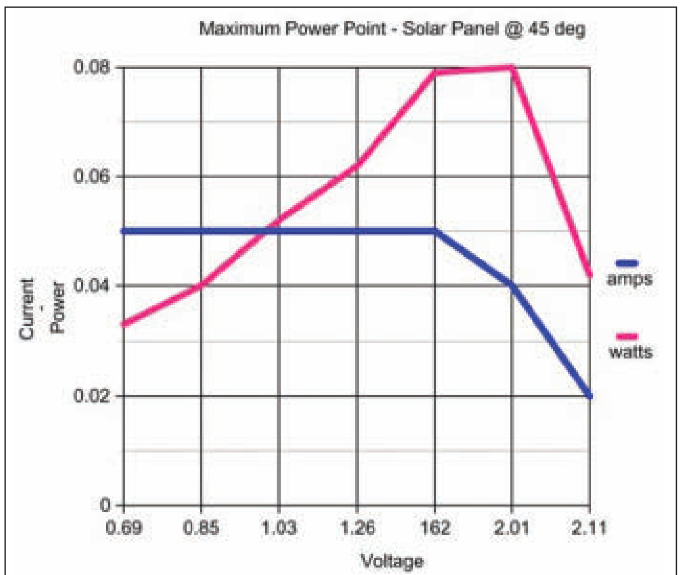


Figure 13 – MPP for Solar Panel at 45º Angle.

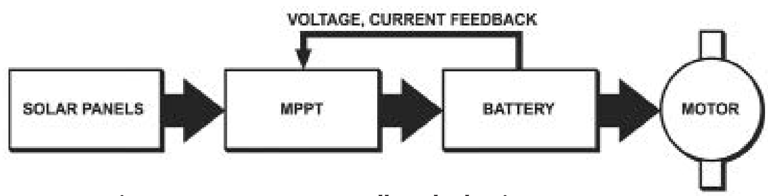


Figure 14 – MPPT Controller Block Diagram.

their conversion; however, expect a 20% to 45% power gain in winter and a 10% to 15% number in summer — consistent with what you've learned about heat. There is a lot more to say about MPPT technology and Boost and Buck converters which are what they are based on, so maybe we'll get into this in another article. It will certainly be worth your time spent since knowing how these devices work and, especially, how to design them will make you stand out in your technical career. It's a skill that many companies want in their technical employees.

Conclusions

Part 1 indicated that a main goal of these articles is to relate how model renewable energy devices compare to real world systems. I hope this article continues to satisfy that goal and that the experiments on the LearnOnLine website inspire you to want to learn more about these renewable energy technologies including extensions to it like the MPPT.

Next time in Part 3, we'll put the BS2 and 28X2 through their paces by building a solar-powered battery charger with automatic charge and shutoff capabilities. This will be a fun and informative exercise because it will bring together a lot of the materials you have been exposed to in Parts 1 and 2, and pave the way as in integral component of Part 4 — another neat solar project that shall go without further mention at this point. In the meantime, conserve energy and "stay green." **NV**

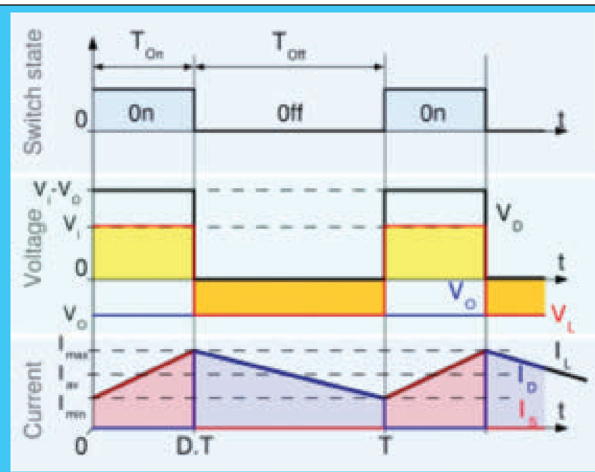


Figure 15 – MPPT Timing in Continuous Mode.

■ BY L. PAUL VERHAGE

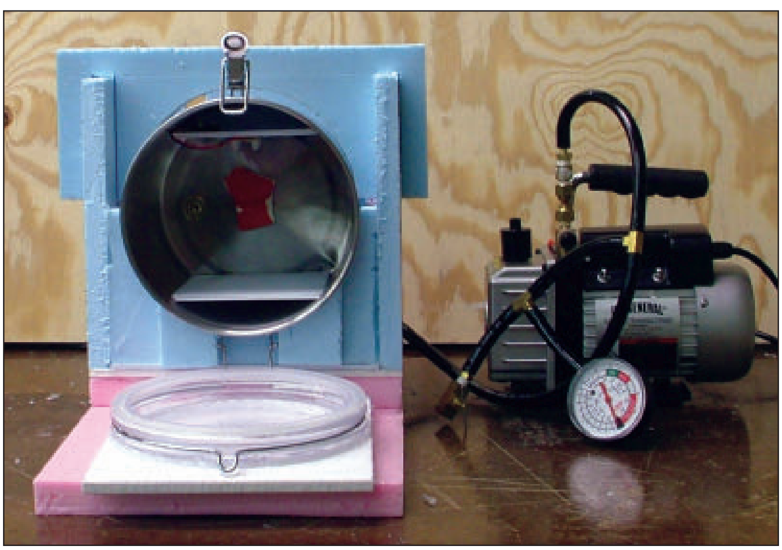
AN ENVIRONMENTAL TEST CHAMBER FOR NEAR SPACE

I'm always on the look-out for neat stuff to do. So, when Mike Manes of EOSS posted over the GPSL* email list that Harbor Freight had discounted a vacuum pump that might be suitable for near space testing, I couldn't resist. My creation takes near space testing to new lows and represents a unique use for an air-tight flour container that the manufacturer surely hadn't intended.

Years ago, I developed a thermal test chamber that was published in the May '05 *Nuts & Volts*. This chill-out box was based on the work of others in the amateur radio, high altitude ballooning (ARHAB) community. It's a fun box for stressing experiments before they take their ride to near space. However, the thermal test chamber only tests for one environmental condition found in near space: extreme cold. It lacked another very important condition: near vacuum. Until I could find an affordable vacuum pump and a suitable container, I was stuck with just testing experiments in the cold.

However, earlier this year word came out that Harbor Freight had discounted their US General 1.2 CFM AC system vacuum pump (part# 98074) to $60. While that's not as cheap as I'd like to see, it does make creating a testing chamber more feasible. Not only did GPSL come through with the idea of using this 1.2 CFM vacuum pump, its members also shared online vacuum container ideas **.

After performing a little research, I decided to try to develop a realistic near space environmental test chamber based on these online references. From there, the project grew until now the final product simultaneously tests for extreme cold, extreme vacuum, increased ultraviolet radiation, and increased cosmic radiation. While the conditions are not tested with 100% fidelity, it's a proof of concept that I can adapt over the next couple of years to create more realistic near space environments in my kitchen.



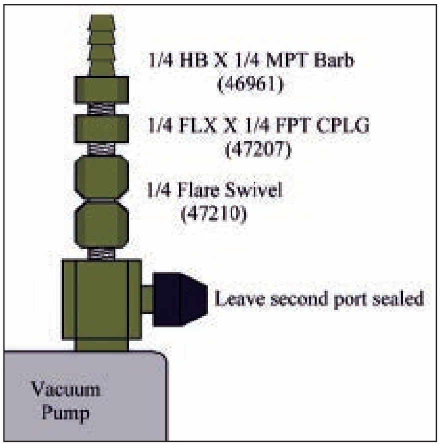
■ The open chamber.

PARTS OF THE NEAR SPACE ENVIRONMENTAL TEST CHAMBER

I ran into a few dead ends while building this test chamber, and depending on your view of things, the final product is a fun exercise in creative construction or a minor plumber's nightmare. You'll be surprised to discover — as I did — that hardware stores don't sell a simple way to connect an air conditioning vacuum pump to an air-tight flour canister. (Go figure.) However, the local Ace hardware was very helpful in showing the correct combination of plumbing parts and pieces to connect the two together.

First, I needed to adapt one of the two ports on the vacuum pump to a 1/4 inch ID fuel hose. The diagram illustrates how this was done. Notice that I used the vacuum pump's top port for this project and left the side port sealed.

Five parts make up the vacuum gauge and vent. The vacuum gauge



■ Three parts convert the vacuum's pump port over to a barb suitable for the 1/4 inch fuel hose. Notice the names of the parts and their Ace part number. You'll find them in a wall of bins in the plumbing section of the store. Be sure to wrap the threads of these parts in Teflon tape first.

is a pressure and vacuum tester from the local CarQuest. It comes with a barb and various fittings since it's designed to test pressure and vacuum in a variety of automobiles. Basically, I threw out the other fittings and kept the gauge with its 1/4 inch barb.

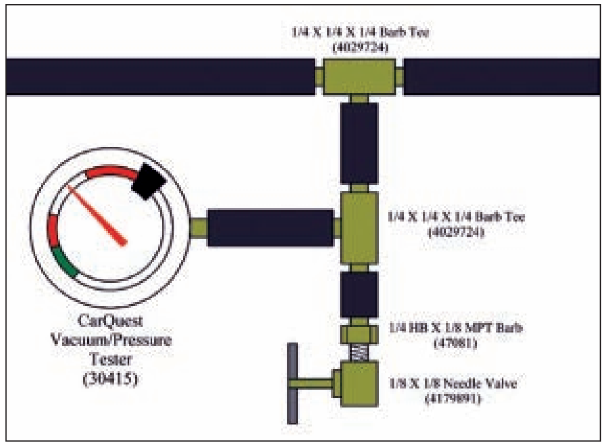
The needle valve is required to let air back into the chamber and open its lid. At full vacuum, there's over 600 pounds of force holding he lid shut. The gauge and vent relief assembly is situated between the vacuum pump and the vacuum chamber.

Next up is the air-tight flour canister — the business end of this affair. Needless to say, an air port wasn't designed into the flour canister — so I had to add one. I didn't have a good way to drill the necessary hole in the canister's stainless steel can, so I asked Dale (the machining teacher at the Kaw Area Technical School or KATS***) if his students could help out. And help out they did. When the canister was returned to me, it had a nice new 1/2 inch diameter hole in the bottom. On Dale's advice, I also placed an o-ring (1/2 inch ID and 11/16 OD — also available at Ace) over the threaded barb before attaching it to the canister with a 1/4 pipe locknut. For good measure, I sealed the barb to the outside of the canister with a bead of silicone glue.

I experimented with several air-tight canisters before getting it right. The first canister design I selected was entirely plastic and had a lid that clamped down to the canister via a latch. Between the lid and the canister was a silicone rubber gasket. This one held up well to vacuum except for an annoying propensity to form tiny cracks in the lid as it was pumped down.

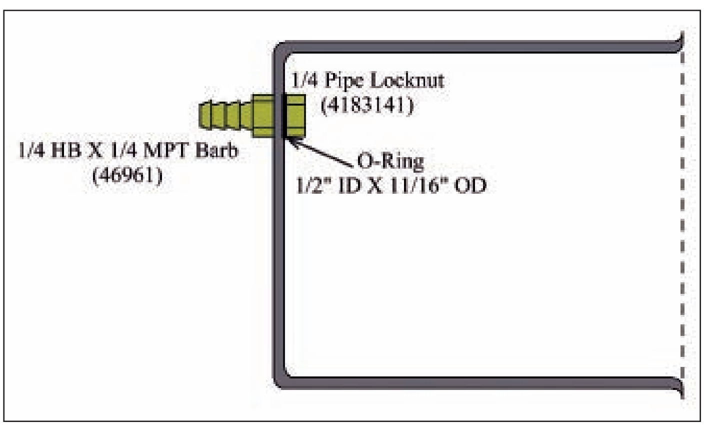
It appears the main body of the canister was thick enough for its cylindrical shape to withstand the force created by the vacuum inside, but the lid was thinner plastic. The thinness of the plastic let it flex inwards when the vacuum was created inside. The lid didn't fail during y testing, but its tiny cracks concerned me. Before giving up entirely with the plastic canister, I did record some great footage on the vacuum exposure of water and a balloon.

I tried a second canister made of stainless steel with a domed lid. Since this lid was thicker and dome shaped,

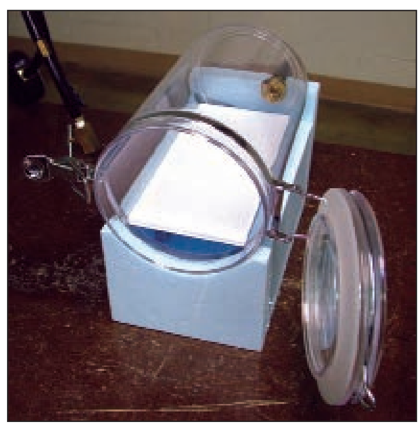


■ The 1/4 inch fuel line is colored black in this diagram.

■ This is the current vacuum gauge and relief valve. The 1/4 inch ID fuel line creates a very air-tight seal with the 1/4 barbs.



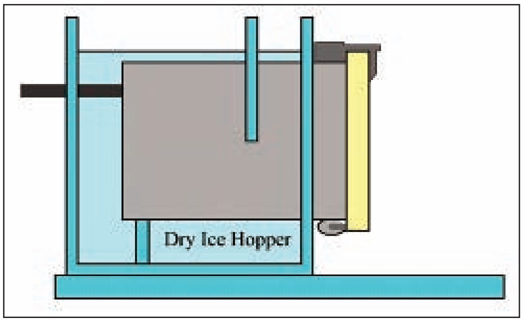
■ An x-ray view of the canister — soon to be an environmental chamber. Not shown in this diagram is the bead of silicone glue covering the barb where it contacts the outside of the canister.



■ Open for business. However, just to be on the safe side, we won't pump this canister down to a full vacuum. Perhaps I can find someone to machine a block of plastic into a new and thicker lid for this canister.

■ A nice domed-lid design, but the cylindrical gasket just can't seal a vacuum well enough — even with its three parallel rows of ridges.

■ This is a great canister for the near space environmental chamber. However, if you're going to make a chamber from it, be sure your wife isn't using it for other things, like storing flour.



■ A side view of the test chamber sitting inside its dry ice hopper. The dry ice is first packed into the bottom, then the canister is set inside. Additional dry ice is then packed around the canister.

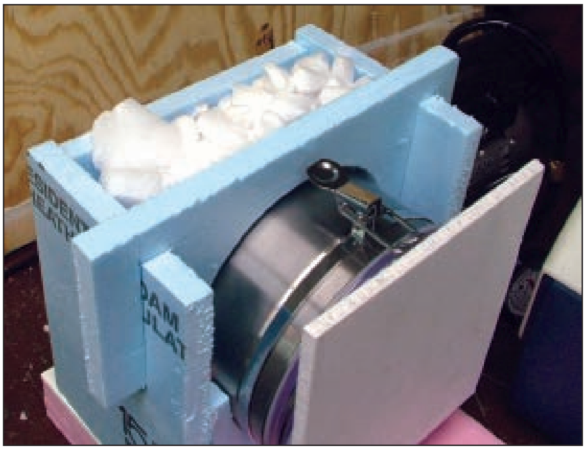
I thought it would withstand the forces of the vacuum inside better than a flat thin plastic lid. However, I discovered its cylindrically shaped silicone rubber gasket didn't seal tightly enough to hold the vacuum (the previous container used a flat gasket). It's a great lid, but not well designed for my needs. However, it was a step in the right direction since its stainless steel body would handle contact with the dry ice without becoming brittle like a plastic canister might. I finally decided to settle on the large stainless steel canister with the thin plastic lid but either find a replacement for the lid or a way to reinforce it. I liked the fact the canister was about eight inches in diameter and 12 inches tall — or large enough for an entire CubeSat to fit inside. Its stainless steel body was safe for the vacuum and intense cool. I could even dump liquid nitrogen over it for the ultimate chilling experience!

The canister was too large to machine a new lid at KATS and I had trouble finding a suitable sheet of acrylic in Topeka, anyways. Therefore, I purchased a plastic cutting board (1/2 inch thick) and got it sawed to the right size to cover the lid. To relieve the pressure on the plastic lid, a hole was drilled into the lid's face to vent air trapped on its outside. Then, the cutting board was glued to the lid with silicone rubber. The glue was applied as a heavy bead along the lid's raised edge. A paint can was set on the old lid to make sure the silicone oozed slightly before it set. The oozing filled any gaps left in the silicone bead.

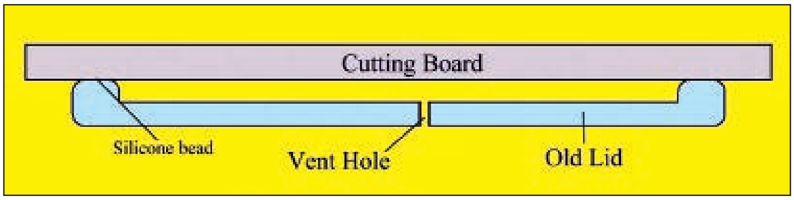
After testing the new lid design, I was ready to complete the construction of the environmental test chamber. Along with a vacuum, I wanted to create temperatures inside the canister that were as cold as I could afford. Dry ice — with its temperature of -109 degrees F — seemed a suitable refrigerant (especially when you consider that it only drops to -60 F in most near space missions). To maintain a cold temperature, the dry ice is packed inside a Styrofoam box (the dry ice hopper) that the stainless steel canister sits in. The pieces of the dry ice hopper were glued together with hot glue since dry ice sublimates to a gas and there's no water to drain from the test stand.

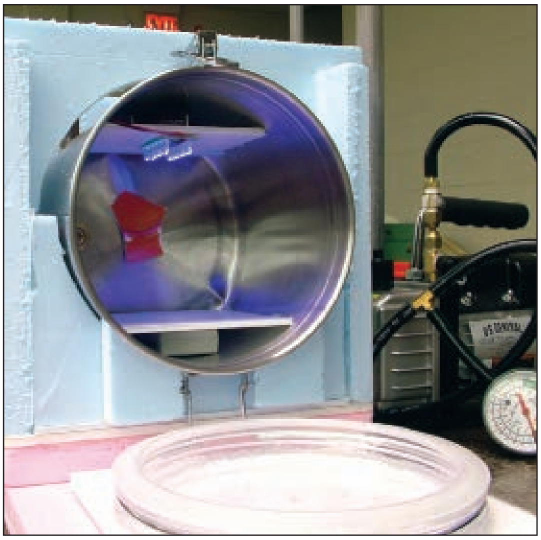
Okay, so now the chamber gets cold and contains a near vacuum, but what about the other conditions found in near space? There's a bank of UV LEDs silicone-glued to the ceiling of the chamber to bathe any experiment inside with ultraviolet. I designed the 20 UV LEDs and their 330 ohm resistors to operate from a nine-volt battery. Because of the intense cold, a Lithium nine-volt battery is required to operate them. It's a neat idea to have an ultraviolet source inside the chamber, but unfortunately, these LEDs operate at 395 nm, or barely within the UV range. When 320 nm UV LEDs become affordable, I'll switch to them. To prevent a possible short, the UV bank PCB attaches to a sheet of Correplast and the Correplast is

■ Here's a photograph I took of the environmental chamber after packing dry ice around it. The Styrofoam sheet between the canister's latch and the dry ice is a removable dam. The dam holds back the dry ice packed behind and on top of the canister. (Man, doesn't that look cold!)

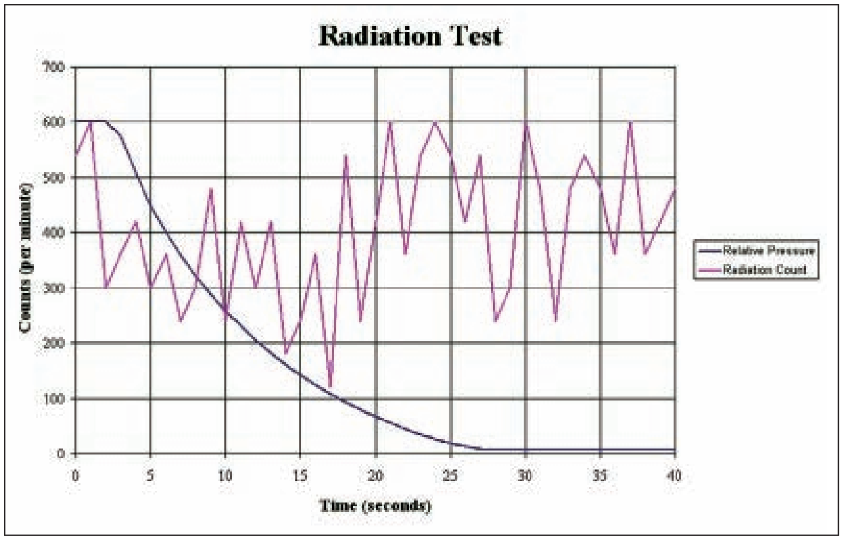


■ A side view of how the plastic cutting board was glued over the canister's old lid. Since there's a small vent hole drilled through the lid, there's no pressure difference to flex the thinner plastic lid inwards (and possibly rupture it).





■ Welcome to my near space nightmare. Inside, you'll find no air, extreme cold, increased radiation, and additional ultraviolet. (Perhaps this is really a fun house instead.) At the top is the bank of 20 UV LEDs blazing away. Against the back you can see the chip of Fiesta Ware and the vacuum port. On the bottom is the platform the experiment rests on. The lid is hinged to the bottom of the canister body so the open chamber lid rests on the ground. That box in the basement is a Hobo datalogger used to measure internal temperatures during tests.



■ I suspected the Aware RM-60 Geiger counter would report a constant radiation background. However, there may be a small increase in background radiation as the chamber approached a full vacuum. If so, perhaps it's because with less air inside, more alpha particles from the Fiesta Ware reach the RM-60 with fewer collisions with molecules. I'll look at running this experiment again for a longer period of time to make sure the randomness of radioactive decay is taken into account.

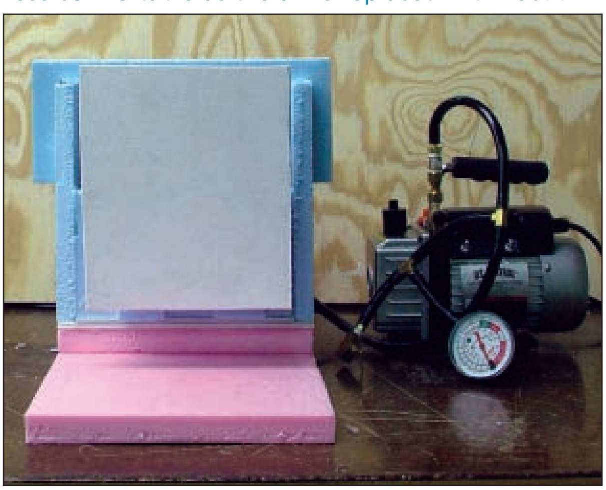
glued to the stainless steel canister. The attic space above the Correplast is large enough to hold the nine-volt battery. The mask and top silk of the UV bank PCB are available on the *NV* website (**www.nutsvolts.com**).

Next, it was time to address the increased cosmic ray flux in near space. The easiest way to create radiation is to use a radioactive source. It can be difficult to find radioactive sources these days. Fortunately, I was given a piece of orange Fiesta Ware — a popular brand of china in the 1950s — to go along with a Geiger counter I was given. The orange glaze of the Fiesta Ware is a uranium-bearing chemical. That makes the orange Fiesta Ware an alpha source, so it's not really very hazardous. A chip of Fiesta Ware was glued to the back of the canister with a blob of silicone glue.

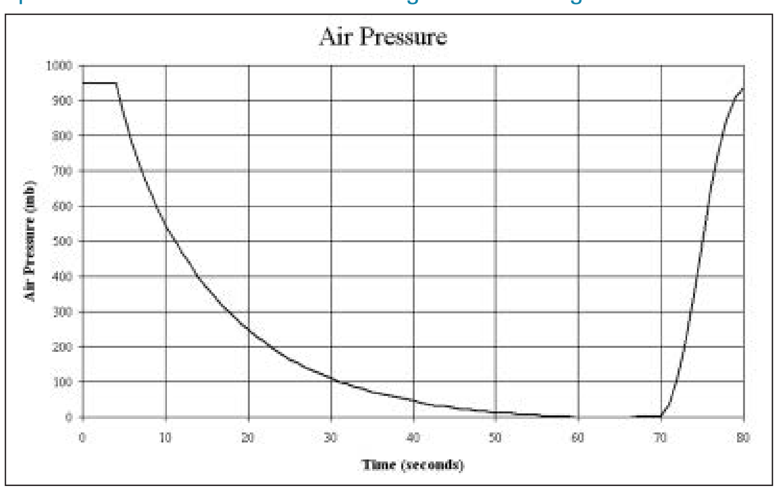
Over time, I'd like to find other commonly available radiation sources to add inside the chamber. This may include Americium from a smoke detector, thorium from a lantern mantle, or potassium from a banana. Since cosmic rays are not primarily alpha particles, it is important to find additional sources of radiation if I want to do a better job of replicating the near space environment.

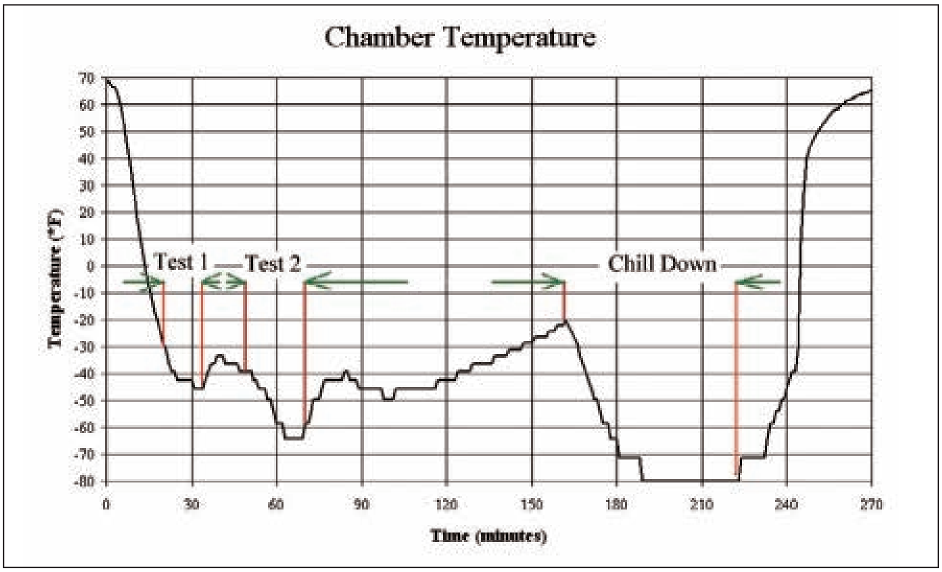
Finally, to protect the experiment inside the chamber from shorting out against the stainless steel canister, I silicone-glued a Correplast platform to the bottom. That gives any experiment a flat, non-conducting surface

■ The experiment is inside and ready for its test. Shortly, the cold interior of the chamber will become less comfortable as the air is replaced with vacuum.



■ An advanced cutdown device took a ride inside the environmental test chamber. The vacuum gauge said the vacuum inside was 29 inches of mercury, which is about 34 mb of pressure. The SM5812 pressure sensor's minimum reading said the test got a full vacuum.





■ The Hobo datalogger was left inside the basement of the test chamber for over four hours. You can see when the chamber lid was closed for each experiment, the temperature dropped. In the final test, we just closed the lid and let the interior of the chamber get as cold as it could.

to sit on inside. The photo shows the final interior of the canister.

TEST RESULTS

The morning after completing the environmental test chamber, I purchased four pounds of dry ice. Then, my students and I packed the bottom of the hopper with dry ice and placed the canister on top (we wore gloves to do this). Next, we placed the dam in position to prevent dry ice from spilling out and added more chunks of dry ice. The chamber was well covered in dry ice except in the front were the lid opened. After packing the experiment inside, we closed and latched the lid. Before running the vacuum pump, we let the experiment chill for a while.

We ran three experiments that morning: one monitored the output from a Geiger counter; one monitored the pressure; and the third monitored the interior temperature. Check out the charts generated from the experiments.

I'd say the environmental test chamber was an unqualified success, but there's still room for improvement. Over all, I only spent about $100 making the test chamber and $60 of that was for the vacuum pump. The stainless steel canister should be very safe for this, as it can only deform and dent (but not shatter) if the pressure on it becomes too great. The plastic, on the other hand, could shatter.

Covering the lid with a flexible and thicker cutting board should remove this risk (don't forget to drill the vent hole through the original lid). Nonetheless, it's always a good idea to wear safety glasses around a vacuum system. I'd also recommend that anyone using this system stand to the side.

Otherwise, have fun making an environmental test chamber and let me know how it goes. Be sure to check out **nearsys.com**, as I should have a link to video up by now.

Onwards and Upwards,
Your near space guide **NV**

NearSys is now blogging. Hear the latest about my near space, astronomy, and robotics exploits at **www.nearsys.blogspot.com**.

* You can join the GPSL near space email list on Yahoo! Groups. It's for and about amateur near space exploration.

** Two of the websites I investigated were:
Parks College Parachute Research
Grouphttp://www.pcprg.com/chamber.htm
The Bell Jar
www.belljar.net/basics.htm

*** KATS is my new digs. If you're in the Topeka area and interested in taking a technical class, pay us a visit at **www.kats.tec.ks.us/**.

ELECTRONET

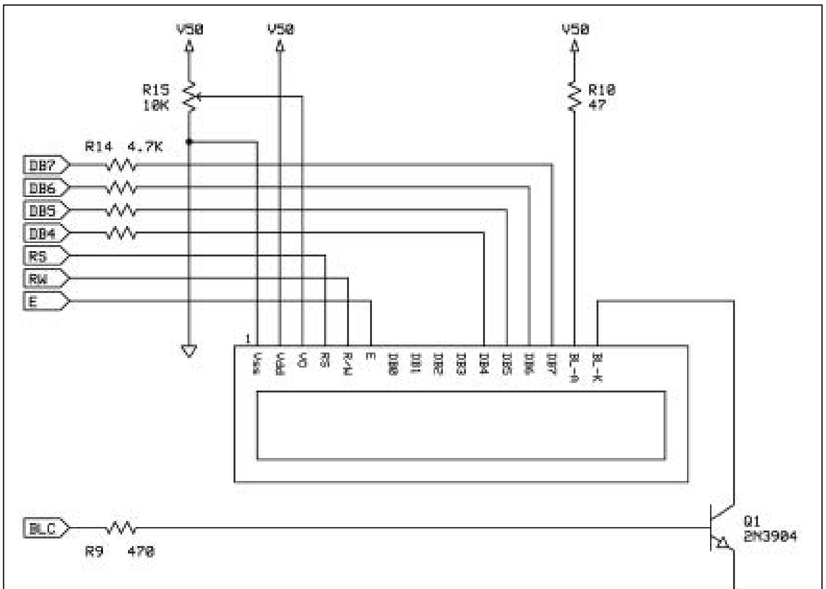
For the ElectroNet online, go to **www.nutsvolts.com** and click **Electro-Net**

■ BY JON WILLIAMS

LCDs & THINGS

It must have been 1994 when I discovered how much I enjoy character LCDs. Like so many others, I got started thanks to Scott Edwards and his articles here in *Nuts & Volts*. As soon as I had one LCD working, I was hooked and have used them with the BS1, BS2, and the SX – so why not the Propeller? To my surprise, there wasn't any particularly good four-bit LCD code in the Propeller Object Exchange so I pulled together my own best stuff and ported it. When we combine the LCD with a mini digital joystick, we have a nice little user interface for projects that move beyond the lab.

Perhaps it's just me, but I find it somewhat humorous that many consider video the standard visual output for the Propeller multiprocessor. Sure, it's really cool, but in my mind it's not very practical for portable applications — and sometimes I want a project to move off my desk! This is where character-based LCDs are eminently practical: They come in a variety of sizes, are low-powered, and are really easy to interface. For my own projects, I tend to use the four-bit interface that is defined by the Hitachi HD44780 specification; the standard which other vendors seem to follow without question. With a four-bit buss, three-control lines, and an output to control the [optional] LCD backlight, we can squeeze the whole works into eight pins (convenient for micros that have eight-bit ports).



■ FIGURE 1. LCD connections.

Figure 1 shows the schematic for the four-bit LCD connections. If it seems like you're having a case of deja vu, don't worry. This schematic is identical to what we used in the SX28-based intervalometer project (*Nuts & Volts* March '09). The only difference is the addition of current limiters on the data pins. Why add these resistors? Well, the Propeller is a 3.3V device and the LCD is a 5V device. When the Propeller is reading the LCD buss, the protection diodes on the Propeller I/O pins will clamp the 5V down to a safe level; these resistors minimize the current through those diodes to protect them.

Before I move on, let me point out something about the LCD called out in the BOM (Hantronix HDM08216-3-L30S): When I plugged it into the board, the backlight turned on. This was odd as there is a transistor circuit to control the backlight and it should not go on without an explicit command. Well, after I proved the control pin on the Propeller was fine and that the transistor circuit was okay, I checked continuity between the cathode (K) pin and ground — they were shorted together on the LCD. I was livid — the spec sheet for the LCD does not indicate that the backlight cathode is connected to ground!

So, despite what we've all been told, I went to bed mad and the next day added a second transistor to the circuit to create a high-side driver that could switch the anode (A) pin with a high output from the Propeller. Then, I noticed something on the LCD: a small solder jumper between the cathode connection and ground. So, I heated up the soldering iron, removed it, and BAM! — everything is working fine with the original circuit. I probably should have noticed that the night before

but I was tired — lesson learned.

So ... if you use the backlit LCD that I call out in the BOM you'll want to make sure that the little jumper (marked J1 on the LCD I have) is removed so that you can control the cathode pin with the single-transistor circuit shown in Figure 1.

Creating an object for the LCD is really quite easy, and as there are no critical timing or "background" requirements, we can do it all in Spin. Let's begin with the initialization of the LCD. We're going to call this method with the first pin of an eight-pin group and pass the number of columns and rows for the LCD.

```
pub init(blpin, cols, lines) | okay

  if (blpin > 20)
    okay := inuse := false

  else
    finalize
    bl   := blpin
    e    := blpin + 1
    rw   := blpin + 2
    rs   := blpin + 3
    db4  := blpin + 4
    db7  := blpin + 7

    if lookdown(cols:8,16,20,24,32,40)
      lcdx := cols
    else
      lcdx := 16

    if lookdown(lines : 1, 2, 4)
      lcdy := lines
    else
      lcdy := 2

    outa[db7..bl]  := %0000_0000
    dira[db7..bl]  := %1111_1110
    lcdinit
    okay := inuse := true

  return okay
```

The code starts by checking the backlight control pin to ensure that the group will not collide with the Propeller I^2C and programming pins (28-31). If the backlight pin number is okay, then the rest of the pins are defined. Some will notice that I maintained the order used by the BASIC Stamp LCD functions — some habits die hard!

With the LCD pins defined, the column and line parameters are validated. As I stated earlier, character LCDs come in a variety of sizes, but there are standards. As 16x2 LCDs seem to be the most common, these values are used as the default settings if a bad parameter is passed. The *lcdx* and *lcdy* variables will be used by other methods to make sure we don't attempt to write to an area of the LCD that isn't present. With the parameters all set, the LCD pins are cleared and all but the backlight control pin are set to outputs; the backlight pin is left as an input for the time being (you'll see why in just a moment).

What we've just worked through is the top-level initialization; after the buss pins have been set up, we call the low-level initialization that puts the LCD into four-bit mode and makes it ready to use.

```
pri lcdinit

  waitcnt((20 * MS_001) + cnt)
  outa[db7..bl]  := %0011_0000
  blipe
  waitcnt((5 * MS_001) + cnt)
  blipe
  waitcnt((150 * US_001) + cnt)
  blipe
  outa[db7..bl]  := %0010_0000
  blipe
  if (lcdy > 1)
    cmd(%0010_1000)
  cmd(%0000_0110)
  dispCtrl  := %0000_1100
  cmd(dispCtrl)
  cmd(CLS)
```

If you've ever used an LCD with a BASIC Stamp or the SX, then this code should look really familiar; in fact,

BILL OF MATERIALS

Item	Description	Supplier/Part No.
LCD	8x2, backlit	Mouser HDM08216L-3-L30S
LED1	Bi-color	Mouser 78-TLUV5300
Q1	2N3904	Mouser 610-2N3904
R1	220	Mouser 291-220-RC
R2	220	Mouser 291-220-RC
R3	220	Mouser 291-220-RC
R4	220	Mouser 291-220-RC
R5	220	Mouser 291-220-RC
R6	220	Mouser 291-220-RC
R7	220	Mouser 291-220-RC
R8	220	Mouser 291-220-RC
R9	470	Mouser 291-470-RC
R10	47	Mouser 291-47-RC
R11	4.7K	Mouser 291-4.7K-RC
R12	4.7K	Mouser 291-4.7K-RC
R13	4.7K	Mouser 291-4.7K-RC
R14	4.7K	Mouser 291-4.7K-RC
R15	10K	Mouser 652-3352T-1-103LF
RN1	10K x 7	Mouser 71-CSC08A01-10K
SW1	4x+1 NO	Mouser 688-SKQUCA
SW2	NO	Mouser 101-TS6211T3202AC-EV
SW2-CAPblack, 12x12mm		Mouser 101-0110-EV
X1	0.1 M-STRT	Mouser 517-6111TG
X2	0.1 M-STRT	Mouser 517-6111TG
X3	0.1 M-STRT	Mouser 517-6111TG
X4	0.1 M-STRT	Mouser 517-6111TG
X5	0.1 Box Header, 16p	Mouser 517-30316-6002
X6	0.1 M-R/A	Mouser 517-5111TG
XLCD	0.1 strip socket	Mouser 517-974-01-16
PCB		ExpressPCB

I copied my SX/B source code for this method into the Propeller editor and then made the [minor] adjustments to Spin. Note that this method is declared as private (**pri**); what this means is that the method cannot be "seen" outside the LCD file, even by an object declared as an LCD. So, private methods are for use only within an object file; public (**pub**) methods may be used internally and externally.

The initlcd() method follows the conventions for four-bit LCD initialization that are detailed in the Hitachi HD44780 datasheet. As you can see, we use *lcdy* to control multi-line initialization. And per usual practices, the LCD is set to auto-increment after a write operation. Finally, we're initializing and using a variable called *dispCtrl*; this will keep track of the display (on or off) and cursor setting (none, underline, blink, or both) so that we can change either without upsetting the others. The starting value of *dispCtrl* turns the display on and the cursor off.

Once the LCD is initialized to four-bit mode, we don't have to write directly to the buss; we can use the cmd() method. This is one of two ways to send information to the LCD. This method sends a command (e.g., clear the LCD, move the cursor, etc.). Another method that we'll use frequently is called out(); we'll use this to write characters. I deliberately named these methods to make the translation of older PBASIC programs as simple as possible.

There is a small, yet critical difference between the cmd() and out() methods: the status of the RS (register select) line to the LCD. For a command, the RS line must be set to 0; for a character, the RS line must be set to 1.

```
pub cmd(c)

  waitbusy
  outa[rs] := 0
  wrlcd(c)


pub out(c)

  waitbusy
  outa[rs] := 1
  wrlcd(c)
```

One of the aspects of LCD interfacing that many programmers give up on is reading the busy flag. We really should read this flag as this enables us to write a new command or character as soon as the LCD is ready; inserting an arbitrary delay just slows everything down and reduces throughput. With a four-bit buss, it takes a little work, but as you'll see it's really not too difficult.

```
pub waitbusy | addr

  dira[db7..db4] := %0000
  outa[rs] := 0
  outa[rw] := 1

  repeat
    outa[e] := 1
    waitcnt((5 * US_001) + cnt)
    addr := ina[db7..db4] << 4
    outa[e] := 0
    waitcnt((5 * US_001) + cnt)
    outa[e] := 1
    waitcnt((5 * US_001) + cnt)
    addr |= ina[db7..db4]
    outa[e] := 0
  while (addr & %1000_0000)

  return (addr & $7F)
```

The method starts by making the data pins inputs and placing the LCD into command (RS = 0) and read (RW = 1) mode. We can read one nibble of the cursor address at a time by "blipping" the enable (e) pin. The high nibble is read first so you see that we have to shift it left by four bits. Then, the lower nibble can be OR'd onto the *addr* variable; if bit7 of *addr* is set, then the LCD is busy with the last command. The address scan is embedded in a **repeat-while** loop that will run until the busy flag clears. Should we ever need to know the address of the cursor, that information is returned by this method.

Before I forget, let me point something out regarding the use of **waitcnt** to do sub-millisecond timing: Spin is an interpreted language and as fast as it is, the Propeller cannot accept a delay value of less than five when using the syntax described here (instruction overhead makes the actual delay longer than 5 µs). I point this out so that you're not tempted to shorten the delays after reading an LCD spec sheet. If we get a **waitcnt** rollover, the delay will go from what we wanted (a few microseconds) to almost a full minute — yes, it takes that long to run through the 32-bit system counter at 80 MHz.

Back to writing to the LCD ... when we've determined the LCD is not busy, we can set the RS line as required (low for a command, high for a character) and then call the wrlcd() method.

```
pri wrlcd(b)

  dira[db7..db4] := %1111
  outa[rw] := 0

  outa[db7..db4] := (b & $F0) >> 4
  blipe
  outa[db7..db4] := b & $0F
  blipe
```

As we're writing to the LCD, the data pins are set as outputs and the LCD to write mode (RW = 0). Again, we have to transfer four bits at a time, starting with the high nibble. After a nibble has been placed on the LCD data

buss, it is transferred by blipping the Enable (e) pin.

When you download the files, you'll see that there are a lot of useful methods in the LCD object and as most are self-explanatory, there is no reason to go into detail here. One method I do want to discuss, though, is called scrollstr(); we can use this to scroll a string through "window" in the LCD.

```
pub scrollstr(x, y, w, ms, pntr) {
} | okay, p, len

  okay := false

  if (x => 1) & (x =< (lcdx + 1 - w))
    if (y => 1) & (y =< lcdy)
      len := strsize(pntr)
      if (len => w)
        repeat (len - w + 1)
          p := pntr
          moveto(x, y)
          repeat w
            out(byte[p++])
          waitcnt((ms * MS_001) + cnt)
          pntr++
     okay := true

  return okay
```

We need to pass the column (x) and line (y) that defines the left edge of the scroll window, the width (w), the delay (in milliseconds) between moves, and a pointer to the string. As you can see, the location and width values are validated before we attempt the scroll; we have to make sure that the defined window will fit onto the LCD (based on its width) and that we've selected a legal line. We also need to ensure that the string is at least as long as the window.

If everything checks out, then a couple nested **repeat** loops do the work. The outer loop controls how many scroll events are required; this is based on the width of the scroll window and the length of the string. Inside that loop, a pointer is set to the first character to print, the cursor is moved to the left edge of the scroll window, then "w" characters are printed to fill the window. After the delay, the character pointer is advanced and the inner loop is run again.

If we want to have a string scroll on cleanly (i.e., start with an empty window), then we need to prefix the string with spaces, at least as many as the width of the window. Conversely, if we want the string to scroll off cleanly, then we need to append a number of spaces to the string to take care of that. It won't take more than a few minutes of play with this method to understand how to take full advantage of it — and remember that pressing F10 in the Propeller IDE downloads very quickly to RAM. If right-to-left is not enough, there is a method called rscrollstr() that does the same thing in reverse (i.e., left-to-right).

GREEN BACKLIGHT CONTROL

Nope, I don't mean green as in the color. I mean green as in energy conservation. The LCD object allows for setting or clearing the backlight, but these are static controls; the backlight is either on or off. What if we create a device that uses a backlit LCD that we're not going to look at all the time — wouldn't it be a good idea to kill the backlight when we don't need it to be operating? You bet, and we can do just that with a very small Assembly program.

Here's the whole works:

```
dat

                        org     0

oneshot                test    osidle, osidle   wc
                        muxc    outa, osmask
                        or      dira, osmask

                        mov     ms1timer, MS_001
                        add     ms1timer, cnt

osloop                 rdlong  ostimer, ospntr  wz
            if_z       muxc    outa, osmask
            if_nz      muxnc   outa, osmask
            if_nz      sub     ostimer, #1
                        wrlong  ostimer, ospntr
                        waitcnt ms1timer, MS_001
                        jmp     #osloop


MS_001                 long    0-0

osmask                 long    0-0
osidle                 long    0-0
ospntr                 long    0-0

ostimer                res     1
ms1timer               res     1

                        fit     492
```

Before I explain the code, let me tell you about the variable section. The first thing you probably noticed are symbols declared as **long** that have a strange value: 0-0. I don't know who started this convention but it is generally accepted among Propeller programmers that this defines a value that will be set or modified by another instruction.

This is possible because all programs are running in RAM; any piece of data — even instructions — can be modified on-the-fly. This is tremendously powerful and tremendously dangerous at the same time if not handled carefully. In our case, we're going to modify these symbols from a Spin method. Until the PASM program is launched with **cognew**, it is just data to the Spin program and can

be changed at will. Making the modifications in Spin is a little easier than doing the setup in Assembly, especially when we want to use fractional values (where division is required) of the system clock frequency.

Here's the Spin code that sets up the one-shot object parameters and launches it.

```
pub init(p, idle, ms) | okay

  finalize

  if (p => 0) and (p =< 27)
    MS_001 := clkfreq / 1_000
    osmask := 1 << p
    osidle := (idle > 0) & 1
    ospntr := @osDuration

    okay := cog := cognew(@oneshot, 0)+1
    run(ms)

  else
    okay := false

  return okay
```

We have to pass the pin number, the idle state (0 or 1), and the number of milliseconds for the initial pulse. If the pin number is legal, then we modify parameters that will be used by the PASM program. The first is MS_001 that is the number of system clock ticks in one millisecond. A bit mask is created for the pin, the parameter called *osidle* is set to 0 or 1 and, finally, the pointer to the one-shot timing variable (which is in the hub) is initialized.

Okay, let's go look at the PASM section. On entry, we test the *osidle* value which was previously forced to zero (idle state is low) or one (idle state is high). The reason we've forced a non-zero value to one is that we're going to use the carry flag to save the idle state. This is accomplished by using **test** on *osidle* against one. The **test** operator works just like **and** but it does not affect the destination. When **wc** is used with **test**, the carry flag will be set (1) if there is an odd number of bits in the **test** result. At this point, the carry flag will match the idle state of the one-shot pin: 0 for low, 1 for high.

Next, we use **muxc** to write the value of the carry flag to the output pin which is defined in *osmask*. With the idle state set the pin is made an output. Since we won't use **wc** in any other instructions, the carry flag will be maintained through the run of the program and we don't have to retest the idle state. Once you get used to the idea of having control over the carry and zero flags, Propeller Assembly can be quite fun.

The next step is to initialize a one-millisecond timer and then drop into the main loop. The first task is to read the one-shot timing from the hub. If the time is zero (**if_z**), we return the pin to its idle state, otherwise we set it to the active state. If the time is greater than zero (**if_nz**), then it gets decremented. We let the one-millisecond timer expire and then we write the timing value back to the hub.

Why bother writing the timing value back to the hub? Well, if we keep the timing variable in one place then both sides can modify it at will; this allows use to truncate a one-shot command if we want to.

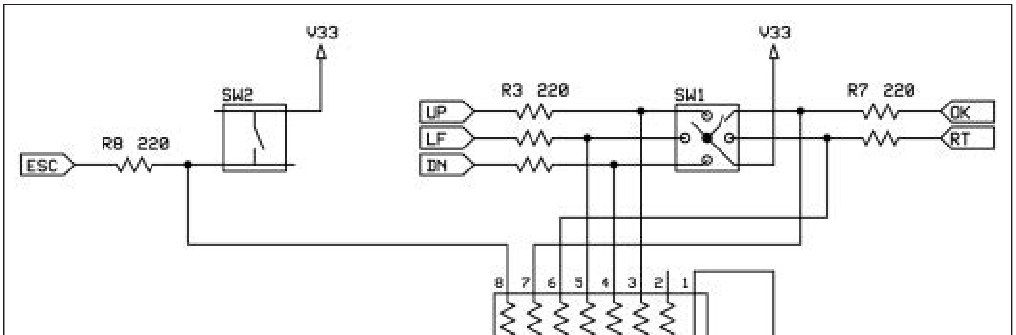
So, how would we use the one-shot control with the LCD? Easy: If a button press is detected (see below), then we'll (re)set the one-shot timer. As long as we're busy with the buttons, the backlight will stay lit; with no input after some pre-determined period (I use five seconds), the backlight will go off and we've reduced current consumption by about 140 milliamps. This is especially useful in battery-powered applications.

THE JOY OF A JOYSTICK

In the December '07 issue of *Nuts & Volts*, Joe DeMeyer described an intervalometer that used a mini digital joystick; the stick has four direction switches plus a center switch. I bought one of these little dudes and it's really cool so I incorporated it into the LCD UI. With the joystick and one additional pushbutton, we have a flexible way of navigating menus and updating information displayed in the LCD. **Figure 2** shows the schematic for the joystick/button interface. All the inputs are pulled low and when active read as "1" on the corresponding Propeller pin.

We all recognize that debouncing switch inputs is a good idea and yet this can take precious time from a program if done in the foreground. So, let's create a debouncing program and run it in a separate cog, shall we?

For flexibility, we're going to pass a mask that defines which pins to scan; a "1" bit in the mask means we'll scan that pin, a "0" bit means the pin is ignored. We'll also pass the debounce timing duration (I tend to use 25 ms) and the



■ FIGURE 2. Joystick and button connections.

logic of the inputs; "1" for active-high (as on the LCD UI board), "0" for active-low (as on the PPDB).

Here's the PASM code that handles the debouncing.

```
dat

                  org       0

debounce          andn      dira, scanmask

                  mov       dbtimer, SCAN_DELAY
                  add       dbtimer, cnt

newscan           mov       scanresult, scanmask
                  mov       scancount, scantime
                  shl       scancount, #3

                  test      scanmode, #1     wz
scan      if_nz   and       scanresult, ina
          if_z    andn      scanresult, ina
                  waitcnt   dbtimer, SCAN_DELAY
                  djnz      scancount, #scan

                  wrlong    scanresult, scanbits
                  jmp       #newscan
```

On entry, we ensure the selected pins are inputs, set up a timer, and then drop into the scan. The scan works by initializing the result to the all pins active — easily done by copying the mask into the result. Then, we test the mode and if active high, the inputs (**ina**) are ANDed with the result; any pin still high will remain a "1" bit in the result — if or until it goes low during the scan. If a pin does go inactive at any point in the scan, the use of AND will cause that bit to stay inactive (0) in the result.

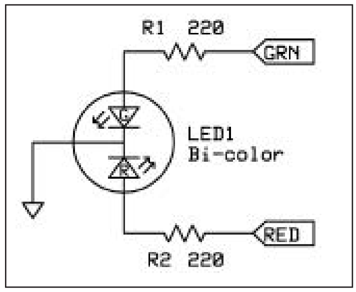
If the scan mode is zero, then we AND the inverted state of the pins with the result; we're able to do this with the (very convenient) **andn** operator. With the inputs scan out of the way, the timer is allowed to expire and the scan count is decremented. When the scan window is completed, the result is written back to the hub and we start a new scan. How easy is that?

Of course, you've noticed that the result bits are active-high ("1" means the input is active), even if the physical pins are wired as active-low. I think this makes the higher level code easier to deal with, especially when creating masks for individual pins.

There are two methods in the high-level interface of the debounce object; one that returns true if *any* of the pins in the mask are active and another that lets us get the state of one or more pins from the debounced result; both methods will be used in the demo program.

BI-COLOR LED REDUX

Since the button inputs only require six bits, it made sense to pop a bicolor LED onto the board — this neatly fills out a group of bits and can provide important information that one might miss on the LCD unless right on top of it. I've had a lot of time to work with the bi-color LED and have made some adjustments.



■ FIGURE 3. Bi-Color LED connections.

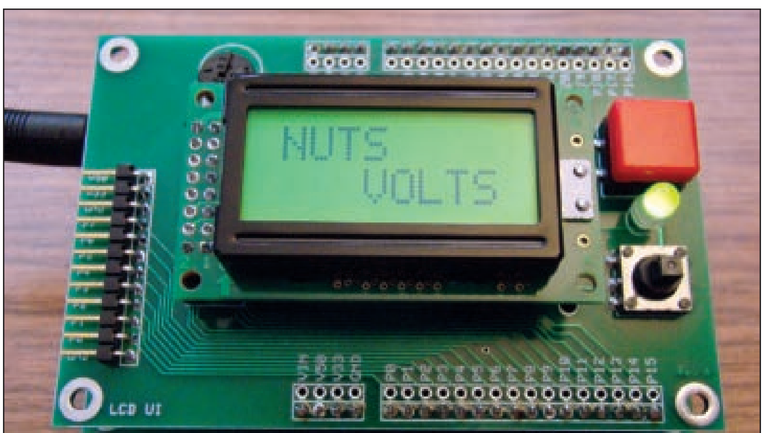
One of the changes is that it now supports two- and three-lead LEDs. The latter usually has a common cathode for the internal LED chips so completely extinguishing the LED means that both pins must be turned off. The bigger change is that the PWM aspect is separated for each color chip. This allows us to balance red and green brightness levels for either style LED, and find the best balance for yellow without having to dig into the PASM code. Have a look at the new object; I think you'll like it.

Figure 3 shows the connections for a three-lead, bi-color LED. If you decide to go with a two-lead type, then you can change one of the resistors to a jumper.

PUTTING IT ALL TOGETHER

Okay, we have an LCD object, a one-shot object that's useful for controlling the LCD backlight, a debounce object for scanning the joystick and button inputs, and finally, an update of the bi-color LED. The LCD UI is an integrated module with pre-defined pin connections so it makes sense to wrap these discrete objects into one master object that we can use in future projects.

Although we use the term "object," Spin is not an OOP language like Java or Python; that is, when we create a new object from others, the methods from the source objects are not inherited by the new object. That's the bad. The good is that we can determine which of the source object methods we want to expose, can rename them if we like, and — of course — we're free to create new methods from those that exist in any of the source objects.



■ FIGURE 4. LCD UI.

For example, you'll find a cls() method in the *lcd_ui* object.

```
pub cls

  lcd.cmd(lcd#CLS)
```

As you can see, this is actually a call to the LCD's cmd() method using the LCD's CLS constant. We'll put this to work in the demo program. As always, I encourage you to experiment with the demo program and then really put it to use. First up for me is connecting an IR LED to the LCD UI expansion buss and porting the intervalometer program that I originally wrote for the SX28.

I'M A GADGET GANGSTER!

If there is a cooler name for a technology-centric website on the Internet, I haven't seen it — **www.gadgetganster.com** has a great name and really fun stuff. Gadget Gangster is run by a nice guy named Nick McClanahan who has taken me up on my "Go forth and be prosperous!" call vis-à-vis projects I create for my columns.

Nick really liked the Propeller Platform and after talking with Ken Gracey at the Propeller Expo in July, it was decided that Gadget Gangster was a better home for the Propeller Platform kit and future kits designed for it (like the LCD UI board). Now, this is not to say that Nick is going to make a kit for every project that appears in this column, but where there's broad interest in a given circuit he probably will.

100 MHz PROPELLER

Until recently, the top speed of the Propeller chip has been 80 MHz. This is derived by using a standard 5 MHz crystal and a PLL setting of 16x. Well, if 80 MHz is good, then 100 MHz is better, right? Absolutely! An enterprising Propeller programmer named Bill Henning has done us all a favor by having custom 6.25 MHz crystals made; this crystal and the 16x PLL setting gives us 100 MHz — a 25% boost in Propeller speed!

One advanced user who has pushed the Propeller even faster suggests changing the Vcc bypass cap near the crystal to a 4.7 to 10 µF tantalum; this is an easy change and the layout of the Propeller Platform accommodates this with no trouble. You can buy the crystals directly from Bill's website (**www.mikronauts.com**), from Parallax, and from Gadget Gangster.

I think that's about enough, don't you? Have fun with the LCD UI and until next time, here's to spinning and winning with the Propeller. **NV**

jwilliams@efx-tek.com
www.parallax.com
www.mouser.com

■ BY FRED EADY

USB-TO-ETHERNET USING MICROCHIP'S FREE STACKS PART 2

Now that we've had a taste of the free Microchip TCP/IP and USB stacks, it's time to put the chocolate in the peanut butter. As promised, this month we'll put a Microchip PIC18F14K50 Low Pin Count USB microcontroller in front of a PIC18F67J60 Ethernet microcontroller and put another RS-232 converter IC out to pasture.

Making things hard is easy. Making things easy is sometimes hard. We'll accomplish this month's USB conversion task without having to design and fabricate a special printed circuit board (PCB). However, if you desire to mount your USB-to-Ethernet creation on a unique piece of copper clad FR4, I don't see a problem with that. We also won't be writing any serious USB or TCP/IP application code for this project as we'll tap into the resources of the free Microchip TCP/IP stack and USB Framework for our firmware magic. In fact, last month we proved that the TCP/IP stack is suitable for use with the PIC18F67J60-based Ethernet hardware we're about to meld with a IC18F14K50-controlled USB front end. With that, let's begin our systems integration task and scratch-build some USB-to-Ethernet hardware.

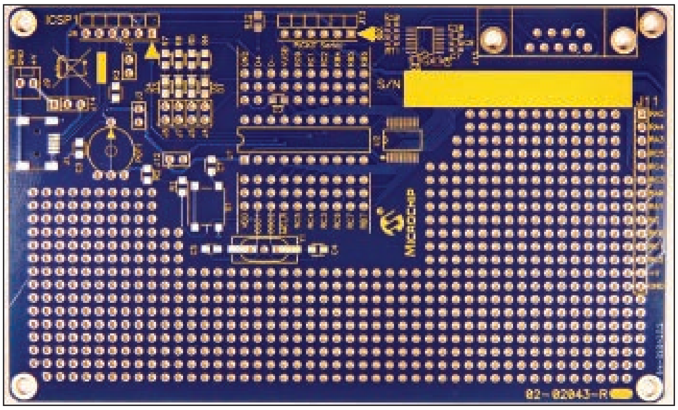
ASSEMBLING THE USB FRONT END

If you've been bitten by the Low Pin Count USB bug and have purchased the Development Kit, you already have a major part of the USB hardware we're about to assemble. In addition to a fully populated PIC18F14K50-based PCB, the Development Kit comes with an identical unpopulated PCB. So, in this case using the bare PCB as the basis for building the USB hardware from scratch is like going camping in a million dollar motor home.

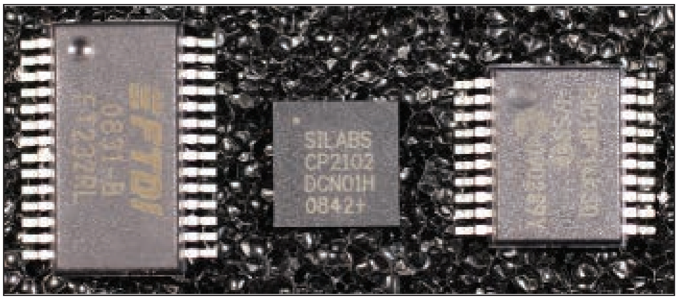
My bare Low Pin Count PCB can be seen in **Photo 1**. Note that the 20-pin DIP pad pattern for the PIC18F14K50 is shadowed by a 20-lead SSOP pad area, which is wired in parallel to the DIP footprint. In our case, it's to no advantage to mount the SSOP version of the PIC18F14K50 as we're not able to save any PCB square footage by doing so. However, the SSOP packaging allows the PIC18F14K50 to be used in the same manner as its FTDI and Silicon Laboratories counterparts. To give you an idea of the size similarities, I've stuffed a trio of the aforementioned manufacturer's USB conversion into the same shot in **Photo 2**. If you have been following my Design Cycle USB discussions, you already know that the FTDI and Silicon Laboratories parts offer a lot of USB bang for the buck. Both offerings have unique and powerful features. The PIC18F14K50 supplies an equivalent bang and throws in microcontroller programmability to boot.

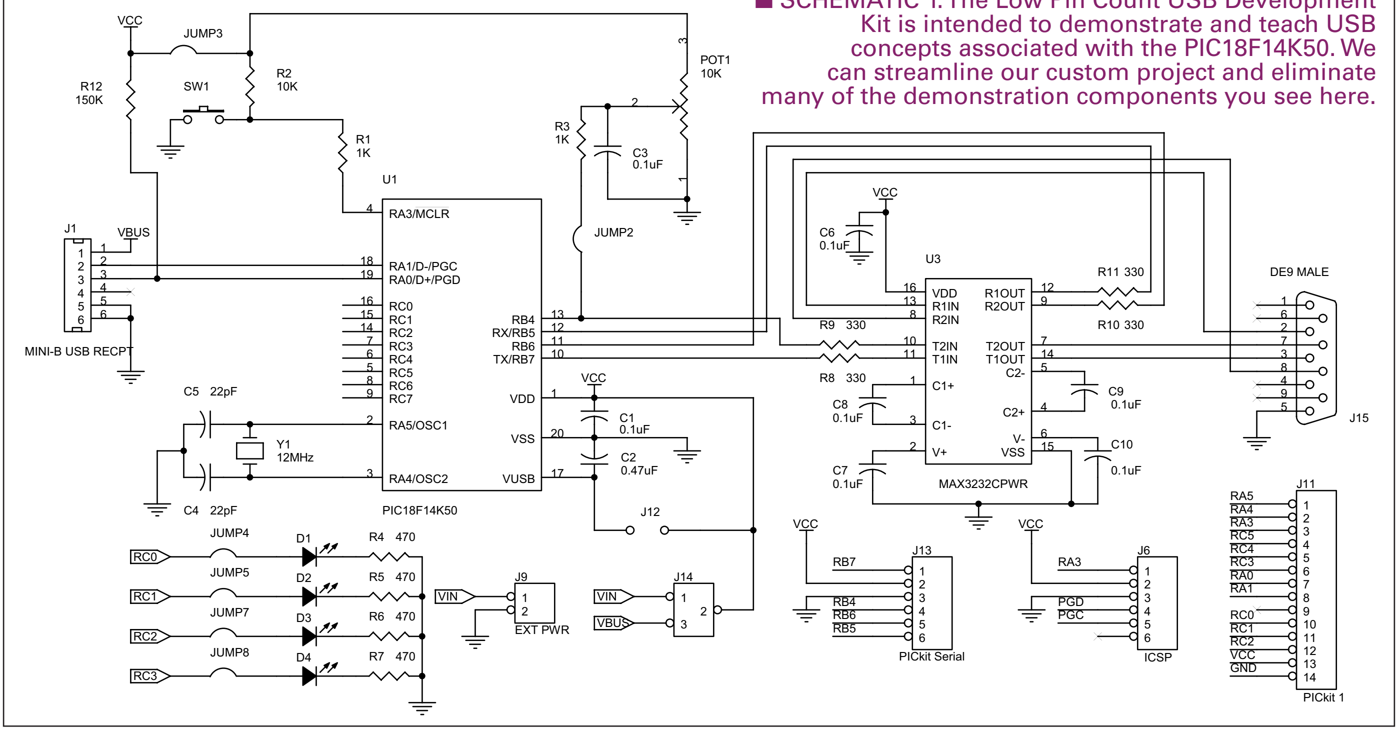
The electrical layout of the official Low Pin Count kit is

■ PHOTO 1. The unloaded Low Pin Count USB Development Kit printed circuit board supports the 20-pin DIP and 20-lead Plastic Shrink Small Outline (SSOP) PIC18F14K50 packages in a mutually exclusive manner. To keep things simple, I've chosen to mount the DIP package using a high quality, 20-pin machined pin socket.



■ PHOTO 2. From left to right we have an FTDI FT232RL, a Silicon Laboratories CP2102, and a PIC18F14K50. The CP2102 comes in with the smallest footprint while the FT232RL has a flexible I/O interface. However, of all of the parts shown here, the PIC18F14K50 is the sole microcontroller-USB combination.





■ SCHEMATIC 1. The Low Pin Count USB Development Kit is intended to demonstrate and teach USB concepts associated with the PIC18F14K50. We can streamline our custom project and eliminate many of the demonstration components you see here.

depicted in **Schematic 1**. Since our goal is to provide a USB interface for an Ethernet communications module, we can eliminate most everything to the right of the PIC18F14K50 in Schematic 1. Pushbutton switch SW1 is mounted for demonstration and training purposes. So, we will eliminate it in our build. The same fate will befall the 10K potentiometer (POT1) and its supporting components resistor R3 and capacitor C3. The absence of POT1, R3, and C3 will negate the use of I/O pin RB4 as an analog input.

Since we will be feeding the Ethernet module's EUSART directly from the PIC18F14K50's EUSART, there is no need to install the MAX3232 RS-232 converter IC and its charge pump and bypass capacitors. For now, we can also put the quad of 330Ω current limiting resistors (R8-R11) on the chopping block. The nine-pin male D connector is of no use to us now that the MAX3232 is not included in the design.

One of the many advantages to converting a legacy RS-232 portal to USB is that the circuit behind the conversion has the opportunity to be powered from the USB interface. If we can keep our total current consumption below the maximum USB port supply current limit of 500 mA, we can throw away that external power supply circuitry and qualify our design to operate in USB powered mode. In anticipation of this, we can ignore the Low Dev kit's external power input pins which are only used in self-powered mode.

Jumper J12 is populated only when the PIC18F14K50's internal 3.3 volt voltage regulator is disabled. Our design requires us to keep the PIC's internal voltage regulator enabled which supplies the correct voltage to the PIC's VUSB pin internally. Thus, we won't set a place at the table for J12. With its internal 3.3 volt regulator enabled, the PIC18F14K50's I/O subsystem is free to operate with five-volt VBUS-compatible logic levels. The PIC18F67J60 — whose EUSART we will be communicating with — requires a 3.3 volt power rail and as a result supports a 3.3 volt logic I/O scheme. In that the PIC18F67J60's inputs are five-volt tolerant (most Microchip 3.3 volt parts are), it's a no-brainer that the PIC18F14K50's EUSART transmissions will be received by the PIC18F67J60's EUSART loud and clear.

On the other hand, the PIC18F67J60's EUSART's 3.3-volt transmit signals may or may not reliably be received by the PIC18F14K50's five-volt EUSART. The PIC18F14K50 datasheet states that if the input pin is a simple TTL buffer, the logical high voltage minimum is 2.0 volts. A Schmitt-trigger input pin requires that the input voltage level be at 80% of the supply voltage to register as a logical "1." That means with a five-volt I/O subsystem, the minimum for a logical high state is 4.0 volts. To assure adequate logic levels in either case, all we have to do is punch a 30-cent CMOS gate between the PIC18F67J60's TX pin and the PIC18F14K50's RX pin.

I can recall a time when simple 7400-series TTL gates costs as much as $5 per IC. Now, a 74HC08 CMOS gate package can be had for about 30 cents. We can chance it and nix the 74HC08 or install a 30-cent part to guarantee success. All of the modifications we've discussed and the 30-cent 74HC08 CMOS AND gate are drawn up in **Schematic 2**.

The 74HC08 CMOS AND gate is acting as a voltage translator. Since the 74HC08 and PIC18F14K50 are both powered from the 5.0 volt USB VBUS rail, the 74HC08's output logic level will be compatible with the PIC18F14K50's I/O logic levels. Thus, any valid CMOS logic voltage applied to the 74HC08 input will result in a TTL-level at its output. There's no need to translate the output of the PIC18F14K50 EUSART as the receiving IC's I/O

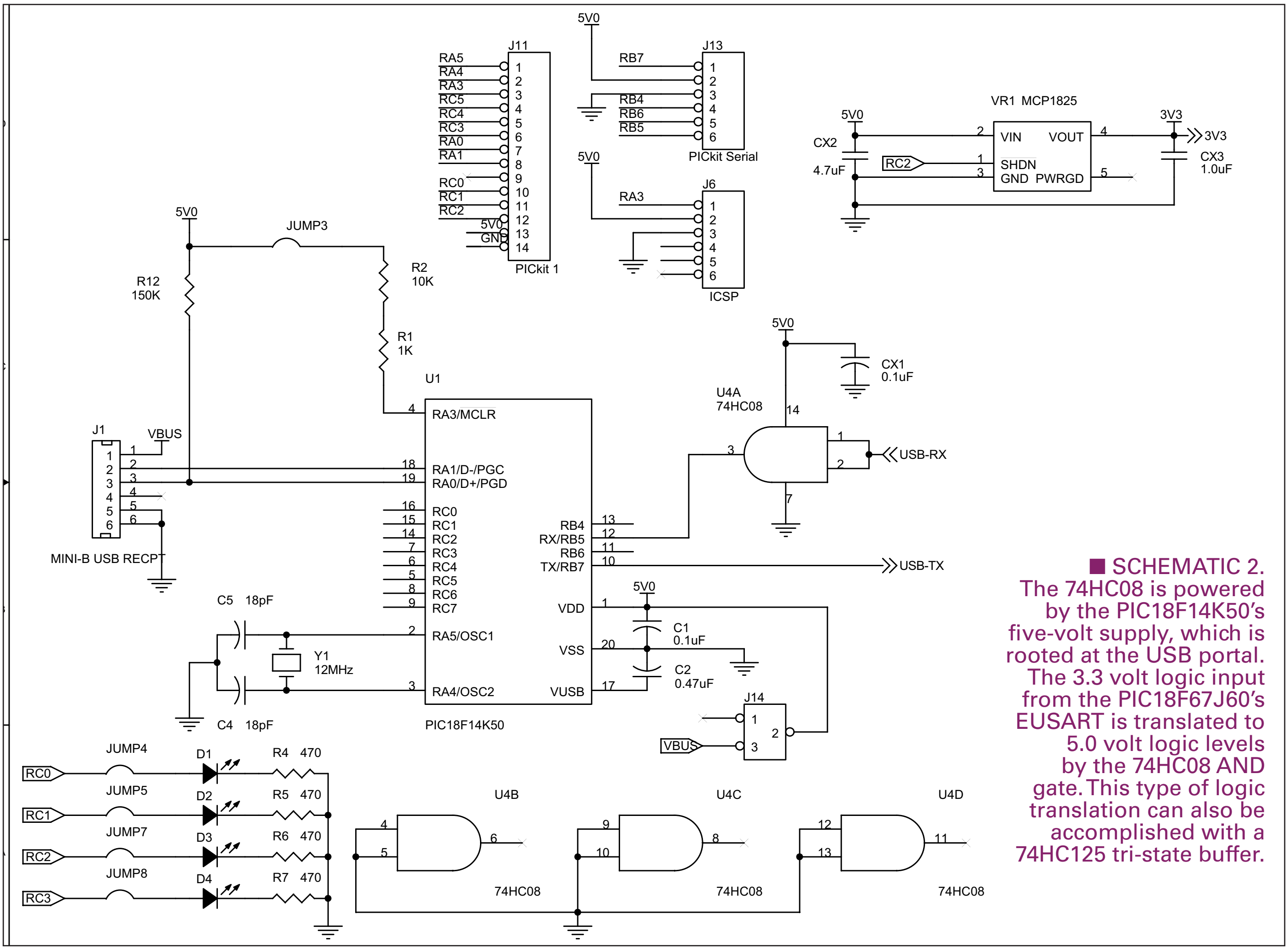
subsystem has 5.0 volt tolerant inputs. However, it's a good idea to place a current limiting anti-latchup resistor in series with the PIC18F14K50's five volt outputs that are feeding the PIC18F67J60's 3.3 volt inputs.

Now that we have the voltage level differentials covered, let's focus on the project's current requirements. The EDTP Ethernet MINI consumes 360 mA of current during normal operation. That leaves 140 mA of USB current budget for the PIC18F14K50 and any supporting circuitry we may want to add. The default USB Configuration 1 Descriptor for the PIC18F14K50 is set to ask for only 100 mA from the USB power source. The PIC18F14K50 draws far less than 100 mA. So, the PIC18F14K50 can be attached to and powered from a USB port with no problems at all. Here's a look at the PIC18F14K50's default Configuration 1 descriptor:

```
/* Configuration 1 Descriptor */
ROM BYTE configDescriptor1[]={
  /* Configuration Descriptor */
 0x09,//sizeof           // Size of this
 (USB_CFG_DSC),          // descriptor in bytes
 USB_DESCRIPTOR_CONFIGURATION,   // CONFIGURATION
                            // descriptor type
 67,0,    // Total length of data for this cfg
 2,       // Number of interfaces in this cfg
 1,       // Index value of this configuration
 0,       // Configuration string index
 _DEFAULT | _SELF,    // Attributes, see
                      // usb_device.h
 50,      // Max power consumption
          // (2X mA) = 100mA
```

A problem arises when the PIC18F67J60-based Ethernet MINI is also powered by the same USB port that is powering the PIC18F14K50. With the USB default Configuration 1 Descriptor in place, the PIC18F14K50 will never completely configure in the USB sense as the actual current consumption will be greater than the requested current consumption value contained within the Configuration 1 Descriptor. This over-current problem is easily solved by requesting the legal maximum amount of current from the USB port. We can ask for it but we don't have to use it. So, we go to the USB current savings and loan by modifying the default Configuration 1 Descriptor:

```
/* Configuration 1 Descriptor */
ROM BYTE configDescriptor1[]={
  /* Configuration Descriptor */
  0x09,//sizeof(USB_CFG_DSC),    // Size of this
                             //  descriptor in bytes
  USB_DESCRIPTOR_CONFIGURATION, // CONFIGURATION
                                 // descriptor type
  67,0, // Total length of data for this cfg
  2,    // Number of interfaces in this cfg
  1,    // Index value of this configuration
  0,    // Configuration string index
  _DEFAULT | _SELF,      // Attributes, see
```



■ SCHEMATIC 2. The 74HC08 is powered by the PIC18F14K50's five-volt supply, which is rooted at the USB portal. The 3.3 volt logic input from the PIC18F67J60's EUSART is translated to 5.0 volt logic levels by the 74HC08 AND gate. This type of logic translation can also be accomplished with a 74HC125 tri-state buffer.

```
                        //  usb_device.h
250,                    // Max power consumption
                       // (2X mA) = 500mA
```

Now that we have permission to draw the maximum current available from the USB port, we must provide a way to allow the PIC18F14K50 to enumerate, configure, and then switch in the high current load. The FTDI FT232R datasheet shows us how to use its active-low PWREN pin to drive a P-channel MOSFET switch, which allows power to flow to user-defined external logic. The PIC18F14K50 doesn't provide a dedicated PWREN I/O pin. However, since the PIC18F14K50 is a PIC, we can programatically create the PWREN functionality. The FT232R activates its PWREN line following a successful enumeration and configuration process. So, we only want to power-up the Ethernet MINI when the PIC18F14K50 has successfully entered the USB Configured state.

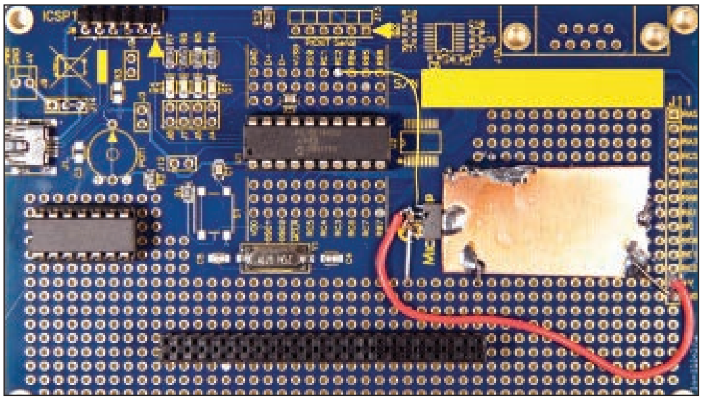
In the case of the USB Framework firmware that supports the Low Pin Count kit, the current state of the USB session is displayed via LED activity, which means we can logically determine the current USB state by monitoring the state of the firmware routines that drive the LEDs. Since only two of the four LEDs are used to display the current USB state, I assigned an unused LED (D3-mLED3) and its I/O pin (RC2) as our pseudo PWREN pin. RC2 is active-high and is only driven high in the Configured state. Here's the code snippet from the *main.c* LED driver function that enables power to the Ethernet MINI:

```
else if(USBDeviceState == CONFIGURED_STATE)
    {
            mLED_3 = 1;
         if(led_count==0)
         {
             mLED_1_Toggle();
             if(mGetLED_1())
             {
                 mLED_2_Off();
             }
             else
             {
                 mLED_2_On();
             }
         }//end if
    }//end if(...)
```

The RC2 pin is driven low in the Detached, Attached, Powered, Default, and Address USB states. Instead of driving the gate of a MOSFET, we will use RC2 to toggle the active–high SHUTDOWN pin of a Microchip MCP1825 voltage regulator. The MCP1825 in our design is housed in a five-lead SOT-223 package and only requires a 4.7 µF ceramic input capacitor and a 1µF ceramic output capacitor. The three-part MCP1825 3.3 volt voltage regulator layout is drawn up in Schematic 2.

As you can see in **Photo 3**, I soldered the ground/heatsink tab of my MCP1825 to a piece of copper plate which has an area of approximately 0.91 square inches. Using 0805-packaged ceramic capacitors, I was able to mount the MCP1825's supporting capacitors directly across the voltage regulator pins. You can also see the 74HC08 and the PICkit2 programmer/debugger interface in this shot.

For those of you that want to duplicate the Development Kit hardware, the USB Mini-B receptacle is available from Mouser (part# 538-67503-1020). The official designation of the MCP1825 voltage regulator is MCP1825T-3302E and can be had from Digi-Key (part# MCP1825T-3302E/DCCT-ND). The dual-row 0.1-inch pitch female header (Digi-Key 929852-01-36) is the attachment point for the EDTP Ethernet MINI NIC. You shouldn't have any problems obtaining the remaining parts from Mouser or Jameco. That pretty much does it for the USB hardware. So, let's begin work on the Ethernet hardware which will be far less labor intensive.



■ PHOTO 3. My MCP1825 heatsink may be ugly, but it works. The 74HC08 is mounted at the far left.

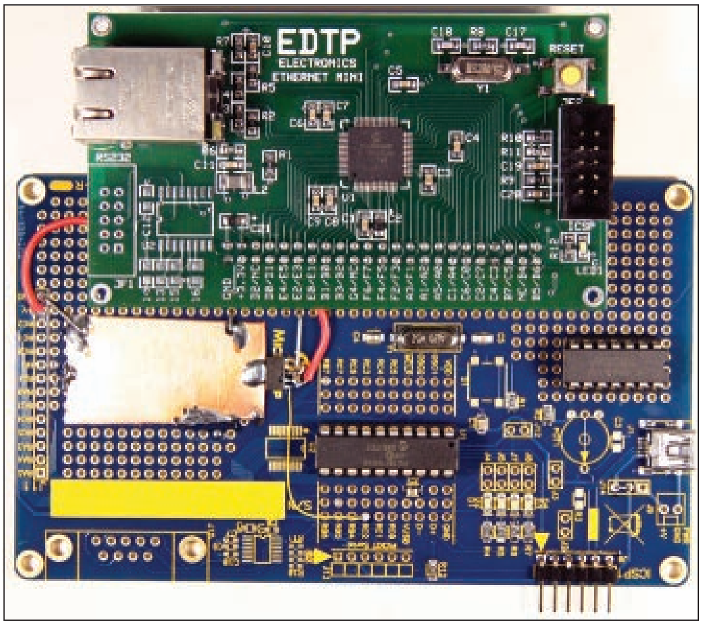
ASSEMBLING AND MATING THE EDTP ETHERNET MINI

The Ethernet MINI can be obtained in kit form from EDTP Electronics, Inc. As a *Nuts & Volts* reader, you can order it at a reduced reader rate from the webstore at **www.edtp.com**. The Ethernet MINI is very easy to assemble and you can get all of the assembly and programming scoop from the EDTP website.

Your Ethernet MINI kit will come with an SP3232 RS-232 converter IC and all of its supporting components including charge pump capacitors, a bypass capacitor, and a 10-pin connector. Toss them into your junk box for later use as you won't be installing them for this project. Referencing **Schematic 3**, you can see that the entire original Ethernet MINI RS-232 interface has been removed from this design. The missing RS-232 parts are also evident in **Photo 4** which is a shot of the USB-enabled Ethernet MINI mounted on the modified Development Kit PCB. You can see some of my point-to-point wiring in Photo 4. As access to the MINI is provided by the male/female header combination, any connections aimed at the Ethernet MINI header were made on the unseen side of the Low Pin Count PCB.

Before mounting the Ethernet MINI, I programmed the PIC18F14K50 and made sure that it would enumerate and establish a USB session with the host PC. I also checked the output of the MCP1825 to verify that the PIC18F14K50 had indeed enabled it and that 3.3 volts were present on the MCP1825's output pin.

After mounting the Ethernet MINI, I again connected the combination of boards to a PC USB port. The



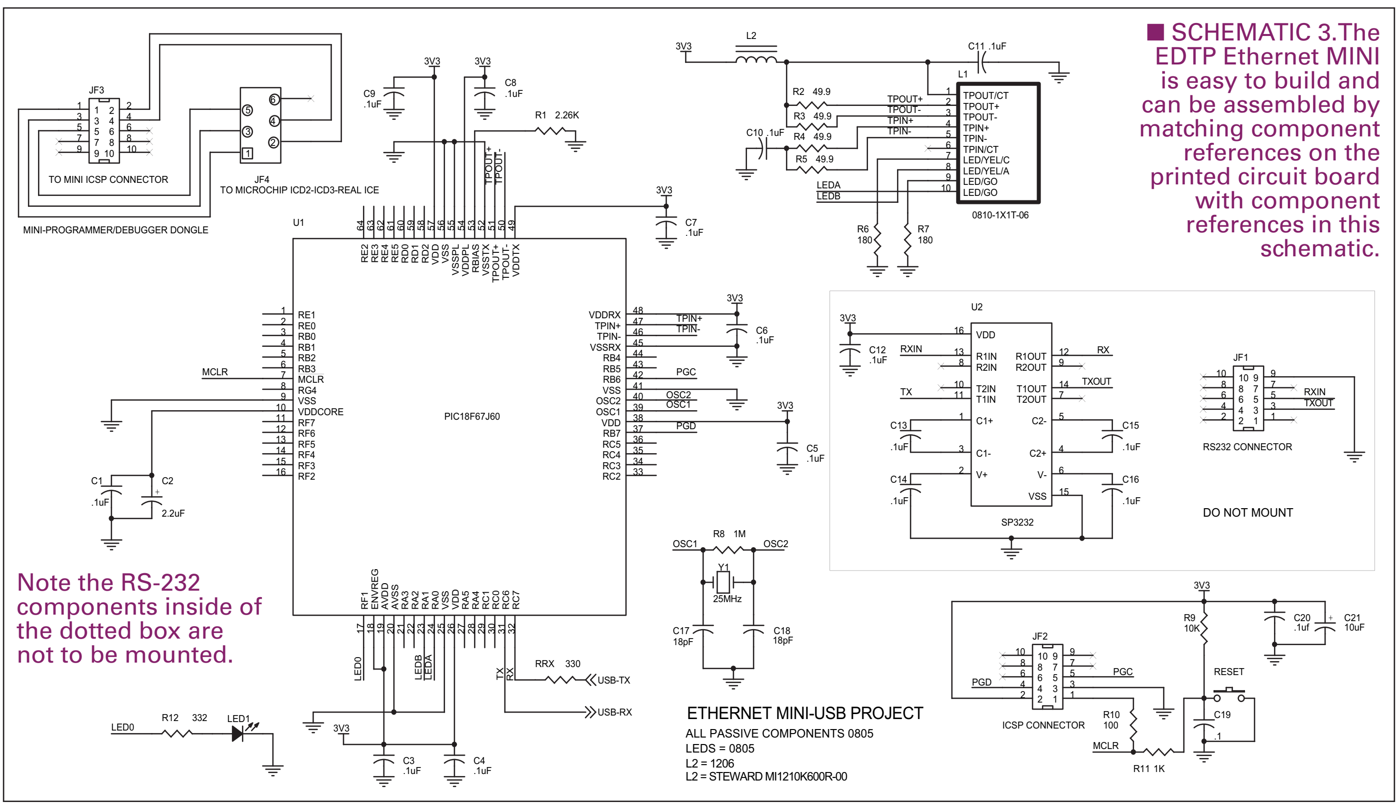
■ PHOTO 4. All of the MINI's resources are accessible from its header. Note the missing RS-232 components.

PIC18F14K50 was able to enumerate and connect. With power flowing from the MCP1825, I was able to program the PIC18F67J60 using a Microchip REAL ICE. With both the PIC18F14K50 and PIC18F67J60 loaded with our application, TCP/IP stack, and USB Framework code, let's see if we can put the project through its paces.

TASTING OUR COOKING

In our overall project design, the PIC18F14K50 is replacing a legacy SP3232 RS-232 converter. Thus, any data transferred between the PIC1's USB interface and the PC is passed through to the PIC18F67J60 on the Ethernet MINI. Conversely, any data traffic flowing through the Ethernet MINI's Ethernet interface will be passed to the PIC18F14K50 and through to the PC. On the Ethernet side sits a standard Ethernet LAN which is overseen by a commercial LinkSys wireless router. The PC in this case is a Lenovo NetBook running Tera Term Pro. I'll run a Telnet session on a Lenovo T61 laptop node attached to the LAN to generate TCP/IP traffic aimed at the Ethernet interface. If all works as designed, we should be able to transfer data between the NetBook's Tera Term Pro session and the T61's Telnet session. Connecting the Lenovo NetBook to our project's PIC18F14K50 USB interface produced the desired alternating D1-D2 LED pattern indicating that the PIC18F14K50 successfully enumerated and entered the USB Configured state. A short time later, LED3 illuminated signaling that the MCP1825 was enabled. The flashing activity LED on the Ethernet MINI was proof of power present at the MCP1825 output.

At this point, we can fire up a MCHPDetect session on the T61 laptop to capture the Ethernet MINI's assigned IP address which will be issued by a DHCP transaction between the LinkSys router and the Ethernet MINI. We can also open a Windows Telnet application on the T61 at this time. Once the MHCPDetect application intercepts the newly assigned Ethernet MINI IP address, we can use the IP address to open a Telnet session between the T61 laptop and the Ethernet MINI. The Telnet session will be used to send data to and receive data from the Tera Term Pro session running on the Lenovo NetBook.



■ SCHEMATIC 3. The EDTP Ethernet MINI is easy to build and can be assembled by matching component references on the printed circuit board with component references in this schematic.

An immediate indicator as to the operation of the USB link is the display of the new Ethernet MINI IP address in the Tera Term Pro window. If configured to do so, the TCP/IP stack will employ an *Announce* application that transmits the newly assigned IP address to the PIC18F67J60's serial port which, in this case, is tied indirectly through the PIC18F14K50's EUSART to the PIC18F14K50's USB interface. The TCP/IP stack *Announce* application also transmits IP and MAC address information to the MCHPDetect application using UDP.

Attaching the CAT5 LAN cable to the Ethernet MINI produced the data you see in the windows of **Screenshot 1**. As you can see, we could have used the Tera Term Pro session to obtain the MINI's IP address. However, we would have had to get up on our donkey and assume that the PIC18F14K50 USB link to the Tera Term Pro application would be up when the MINI received its new IP address.

Armed with a valid IP address for the Ethernet MINI and an assurance that the Tera Term Pro session is operational, we can open and establish a Telnet session between the T61 and the NetBook. Note the port address of 9761 in the Telnet window of **Screenshot 2**. The port address shown in Screenshot 2, as well as the PIC18F67J60's EUSART baud rate, are defined in the UART2TCPBridge application that is part of the Microchip TCP/IP stack:

```
#define UART2TCPBRIDGE_PORT  9761
#define BAUD_RATE            19200
```

If you're wondering why there isn't a Telnet window running on the NetBook, remember that the Microchip Windows USB driver emulates a standard COM port. Hitting the ENTER key in the Tera Term Pro session cleared the screen at the Telnet end and allowed me to send the message you see in **Screenshot 3** from the NetBook Tera Term Pro session to the T61 Telnet session in the clear.

FROM USB TO THE INTERNET

Think about this. You now have the ability to contact a device operating on a LAN or the Internet using RS-232 signaling via a USB port. Conversely, you can reach out and touch a device through its USB port from the big cloud or that little cloud in your home or office.

All you need to move on your own USB-to-Ethernet communications project is a copy of Microchip's TCP/IP stack, a copy of the Microchip USB Framework, a bare Low Pin Count USB Development Kit PCB, and an EDTP Ethernet MINI. I'll post all of the project code for you on the *Nuts & Volts* site (**www.nutsvolts.com**). You now have permission to add oak leaf clusters to the USB and Ethernet skills that are already in your Design Cycle. **NV**

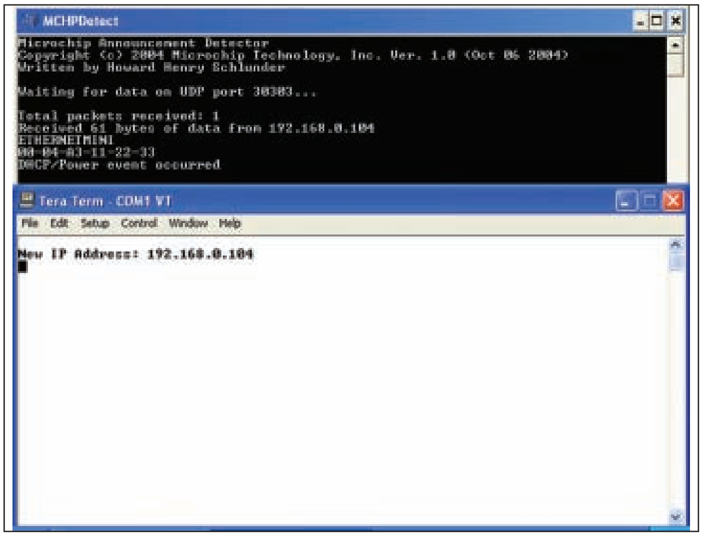
SOURCES

Microchip TCP/IP Stack
Microchip USB Framework
Microchip REAL ICE
MCP1825
PIC18F14K50
PIC18F67J60
Low Pin Count USB Development Kit
Microchip
www.microchip.com

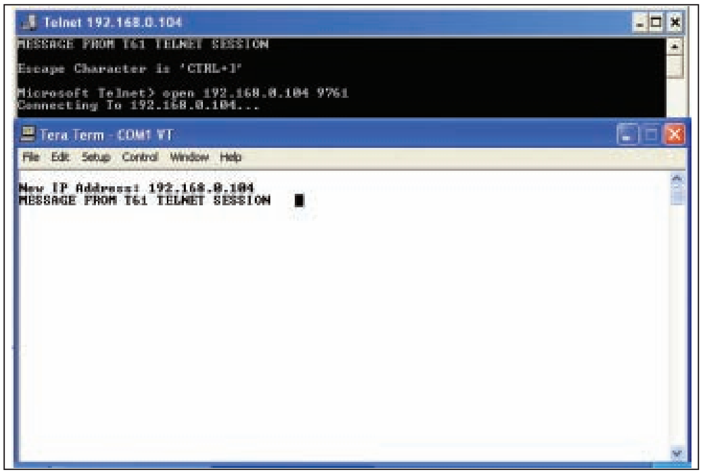
FT232RL
FTDI
www.ftdichip.com

CP2102
Silicon Laboratories
www.silabs.com

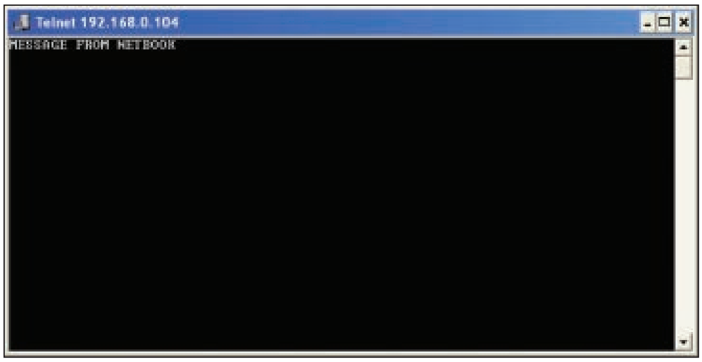
Ethernet MINI
EDTP Electronics, Inc.
www.edtp.com



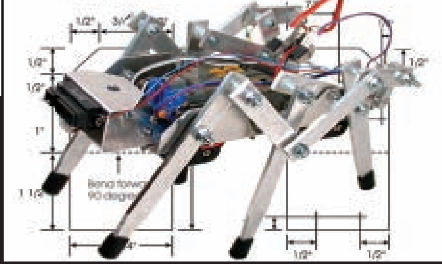
■ SCREENSHOT 1. The Microchip TCP/IP stack Announce application can also service an LCD. Here the information is transferred via UDP and RS-232. The RS-232 message is converted to USB by the PIC18F14K50.



■ SCREENSHOT 2. Don't let the sequence of events in the Telnet window fool you. I typed in the T61 message over the Telnet welcome banner.



■ SCREENSHOT 3. Be sure to turn on local echo if you want to see what you are sending at the Tera Term Pro end. Tera Term Pro defaults to local echo off.



■ BY VERN GRANER

THE DUNGEON KEEPER

BOO! Don't look now, but it's almost that time again! Before you know it, those little trick or treaters will be ringing your door bell demanding their treats. I feel the very least we can do is give them a scary good time, eh? So, how about we make an animatronic body for our talking skull and put him in a creepy coffin so he can beckon them forward with a flickering candle? Though this may sound like a pretty big project, it's actually rather straight-forward and, if you start now, you should be able to have your own Dungeon Keeper ready to thrill the kids and wow the parents for this Halloween! I had to invent my own talking skull, but if you already have the Talking Skull kit featured in the September '08 issue of *Nuts & Volts*, you literally have a head start!

THE HAUNTED TOWER

In the fall of 2003, my family and I had just moved into a new house in a new neighborhood. We thought we might be able to meet our neighbors if we really put on a show for Halloween as the area was teeming with kids. We came up with a design for a "renaissance" haunt motif simply using some black landscaping plastic and some white paint to create the facade of a castle tower. We prototyped the concept in a doorway of the house and it came out very cool (especially in the dark when back-lit!). So, we took the concept and ramped it up, painting a two-story tall piece of black plastic and then hanging it up on the front of our house (**Figure 1**). We called it "The Haunted Tower."

■ FIGURE 1. The large-scale tower facade. (inset) The Haunted Tower facade in place.

Unfortunately, inside our very scary Haunted Tower was a rather non-scary contemporary front door. I decided to replace it with a home-built "dungeon door" that had a speak easy type of sliding peep hole to allow us to interact with visitors (**Figure 2**). The speak-easy peep-hole was large enough to allow someone in costume to interact with the trick or treaters (**Figure 3**), but I didn't like the idea of some guy in a mask (likely me) getting stuck with poking his head out the door to say "boo!" all night. I wanted to try my hand at a fully animatronic character. I figured a "talking skull" type creature would be perfect so I went on a quest for a decent model skull I could convert into my Dungeon Keeper.

GETTING A HEAD

Back in 2003, when I first envisioned creating a

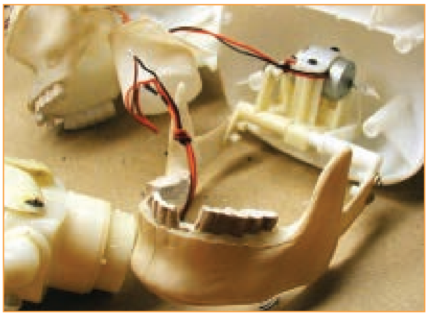
talking skull for my Haunted Tower, I hadn't yet discovered the Talking Skull Kit so I decided to roll my own. I started by searching for something I could hack into a scary animatronic prop. As luck would have it, I found a novelty singing "Big Head" skeleton from a big-box store here in town.

I removed the skull from the small plastic body, then opened the skull to discover a small DC motor that was used to open the jaw (**Figure 4**). This is fairly typical in this type of low-cost animatronic as the driving circuit simply applies power to the motor and it moves to a stall point until power is removed. This causes the mouth to open and close but it really gives you very little control over the position of the jaw. I decided a servo motor would do a much better job and would allow me to control the position either via programming or by using a circuit to convert audio to servo control signals.

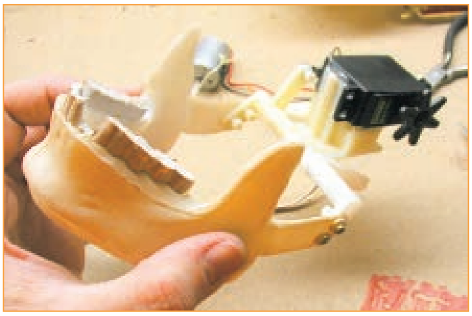
I removed the DC motor and modified the mount to hold a servo motor (**Figure 5**). I then reassembled the jaw and tested the motion using my RC control system (**Figure 6**). The jaw worked very well, was very responsive, and relatively quiet. So, now that I had jaw motion, I decided that the simple red LED eyes had to go.

■ FIGURE 2. The Dungeon Door with peep hole closed.

■ FIGURE 3. The Dungeon Door with peep hole open and masked monster showing.



■ FIGURE 4. The DC motor in the jaw motion assembly.

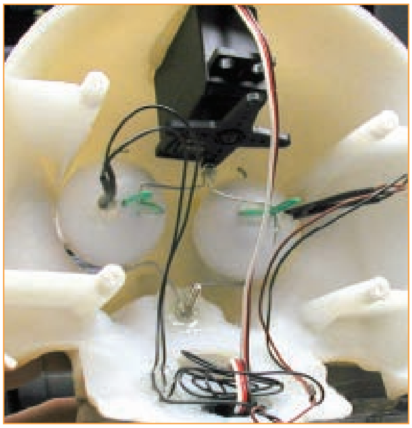


■ FIGURE 5. The new servo motor in place in the jaw.

ANIMATRONIC EYES? I SEE!

After removing the red LEDs, I used a Dremel tool to remove some plastic material from around the eye sockets. This made a large enough area to allow the installation of hard plastic eyeballs that I had found at a party/novelty store (**Figure 7**). I bent a large paperclip to make a gimbal that would hold both eyeballs while allowing them to turn left and right. Another paperclip created the gimbal at the rear of each eyeball that allowed the servo motor to pan the eyes left and right (**Figure 8**). I decided against trying to fabricate an up/down mechanism as the skull would have the ability to look down by tilting (just as soon as I gave him a neck to stand on!). I added blue colored LEDs to the backs of each eyeball so I could make them glow and ran the wires for the servos and LEDs down through the throat of the skull.

■ FIGURE 6. Testing the servo controlled jaw motion on the reassembled skull.



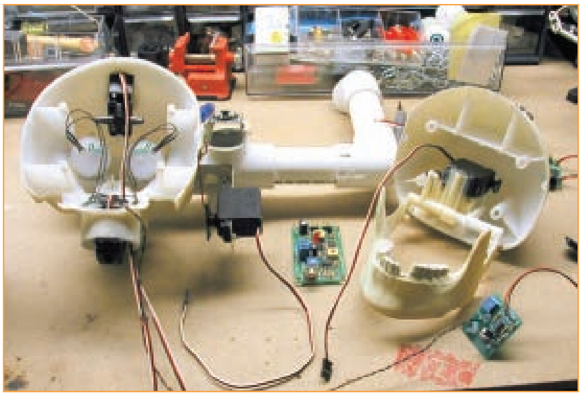
■ FIGURE 7. Eye motion servo connected to eyeball gimbals.

■ FIGURE 8. Front view of skull with servo operated eyes.

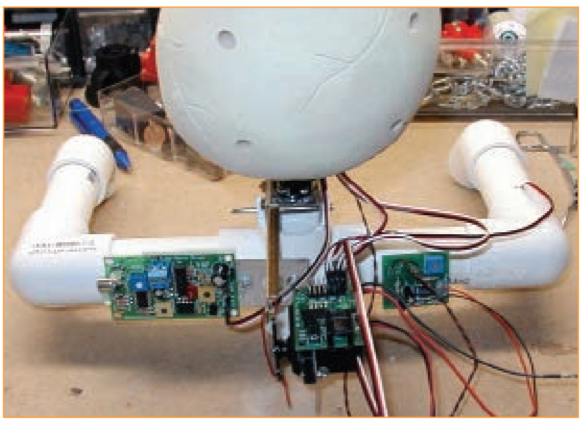
I AIN'T GOT NO BODY!

For me, PVC = EZ! You can make things

■ FIGURE 9. PVC body with hips mounted flush to the Dungeon Door; arms extend through the peep hole.



■ FIGURE 10. PVC shoulders with skull tilt gimbal in the center.



■ FIGURE 11. PVC Shoulders with skull attached and all electronics in place.

■ FIGURE 12. The Dungeon Keeper greets trick or treaters at the Dungeon Door on Halloween.

that friction-fit together very well and are surprisingly strong. The parts are relatively inexpensive and if you decide you want something a bit more permanent, all you have to do is add a bit of PVC cement to your design. The fact that the PVC pipe is hollow and makes for easy wire runs is an added bonus.

So, when I needed a neck and shoulders to place my animatronic skull on, I just went out to the garage and dug around a bit in the bin of PVC fittings I have. I came up with some 3/4" PVC that I quickly shaped into a neck, shoulders, wrists, and torso that fit perfectly on the back of the Dungeon Door (**Figure 9**). After the test fitting on the door, I removed the neck and shoulders and took them back to my work bench to figure out how to mount the skull.

To give the skull the ability to pan left/right, I added a servo motor into the neck of the skull facing down (this turned out to be a less than optimal design choice as I will describe later). I then built a small platform on the top of the PVC shoulders that would allow the head to tilt up and down (**Figure 10**).

By this time, I had finally discovered Scary Terry's sound-to-servo board and I had ordered a kit from Cowlacious Designs. I mounted the sound-to-servo control board on the left shoulder, a serial servo controller in the center, and an LED PWM fading circuit on the right shoulder (**Figure 11**). I added a flickering neon candle and a pair of skeleton gloves to finish him up and he was ready to scare some trick or treaters and hand out candy (**Figure 12**).

SHOW TIME!

When the big night arrived, we had kids coming from all over the neighborhood dragging their parents to come see the talking skull in the scary tower! Though the night was a big success and I really like the effect of him mounted in the Dungeon Keeper, there were a few issues that made me reconsider. For example, to operate the prop you would open the peep hole door, then lean the body of the Dungeon Keeper out the window. This seems simple enough, but in practice, it's kinda tough to pull the rope to open the peep hole, tie it off, and push the Dungeon Keeper forward through the window all while trying to trigger the audio sound track, activate the animatronic motion, and juggle a bowl of candy! At one point during that first night of operation, I pulled open the door and slammed the body forward in an attempt to give the kids a good startle. Unfortunately, when his body hit the door, his skull snapped off at the neck and was

■ FIGURE 13. Kym Graner fits together pieces of the Toe Pincher Coffin.

Bruce Tabor adds internal reinforcements to the coffin.

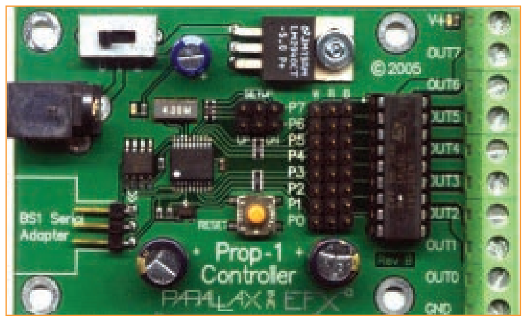
left dangling outside the door by its wires!

I managed to put his head back on with hot melt glue and wire ties so he lasted out the evening, but this was a good lesson for me on designing for stress situations. Based on this experience, when I overhaul him, I plan to remove the servo from his throat (the one that controls head pan) and place it below the skull (like the tilt servo) so all the weight of the skull will be taken by a gimbal to avoid this issue in the future.

The little "Oops! My head popped off!" issue wasn't the only problem with the design. The door itself was rather large and cumbersome, and provided little protection for the skull and the somewhat delicate wiring and electronics that were exposed on the back side. Also, if taken out to show, people would be able to clearly see behind the animatronic making it harder to stage for performance.

Lastly, the sheer size of the door plus the exposed electronics made for difficult storage as the unit wouldn't lay flat, and the electronics and moving parts were all exposed to accidental damage. All in all, it was time to consider a different box for this project.

■ FIGURE 14. The complete toe pincher coffin after painting, hardware, and interior finished.



■ FIGURE 15. The EFX-TEK Prop-1 board.

A PROJECT BOX TO DIE FOR!

I've made all sorts of enclosures over the last couple of decades to house various projects, but this project box would be the biggest I'd ever made. I ran across the "Single Sheet of Plywood Coffin" plans when perusing the monster list of Halloween projects sometime in 2004 (see Resources). Originally developed by **CasaDeSade.com**, this ingenious design creates a life-size coffin from a single 4' x 8' x 1/2" sheet of plywood!

■ FIGURE 16. The Dungeon Keeper animatronic after transplant into the coffin (undressed and dressed).

As always, I turn to my friends when I need expert help. It just so happens that my good friend (and carpenter by trade) Bruce Tabor was kind enough to offer use of his table saw, pneumatic nailer, and top-notch carpentry skills to speed up the construction of the coffin. We cut out all the pieces and then assembled them using a bit of scrap lumber to hold the corners (**Figure 13**). Once painted, we had a pretty amazing haunted house prop (**Figure 14**).

Since I planned to transplant the Dungeon Keeper animatronic into the coffin, I discovered this made a lot more sense than leaving him mounted to the Dungeon Door. For example, the coffin gave us a place to keep the power supply, lights, a nice sound system with a sub

Das BlinkenBoard Update!

Once again, Das BlinkenBoard comes to the rescue — this month in the form of a theater and haunt safe candelabra! With the help of Marvin "Professor Conrad" Niebuhr, we have placed a BlinkenBoard inside a PVC and wood stage prop candelabra. Using the default flame simulator program built into the microcontroller, we can simulate flames by placing one red and one yellow LED in each of the four cups, then use some hollowed out candles to act as diffusers. This is a work in progress with more details to come in the next issue!

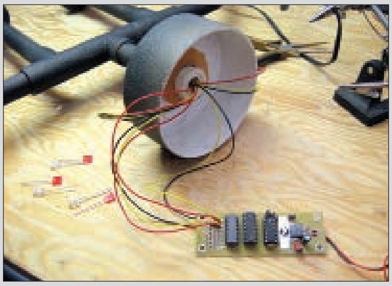
PVC pipe ready to be assembled.

Assembled candelabra.

Primed, textured, and painted.

Wiring the left side.

Wiring the right side.



Attaching Das BlinkenBoard to the base.

The LEDs ready to be attached to each candle holder.

Red/Yellow LEDs ready to go into candles.

woofer, a CD player, and even a microcontroller.

RANDOMLY SCARY?

When the Dungeon Keeper was first used, I had head tilt, head pan, and eye pan which were all controlled by a Windows computer using software from Reynolds Electronics called "Robo-Ware" (see resources). This software allows you to choreograph the position of each servo by setting targets. Though you can create very precise motions using the software, the downside is that you must specifically program each position for each servo and — as you might imagine — this can be very time-consuming. However, if you want very precise control of your animatronic creation, it's a very good choice.

In my situation, I planned to use the Dungeon Keeper in a number of different scenarios and didn't want to hassle with creating new motion programs for each show. I decided

RESOURCES

Videos of The Dungeon Keeper
www.youtube.com/VernGraner

Talking Skull Kit
http://store.nutsvolts.com/home.php?cat=388

Monster list of Halloween Projects
www.halloweenmonsterlist.info

The Halloween "L" - Halloween Enthusiasts Chat
www.wildrice.com/Halloween-l

Technical Insanity: NO chat, Just Tech Talk
http://groups.yahoo.com/group/Technical_Insanity

One Sheet of Plywood Coffin
www.shallowvalley.com/pincherplansprint.html
www.notepad.org/DungeonKeeper

Robo-Ware Servo Automation Software
www.rentron.com/Robo-Ware.htm

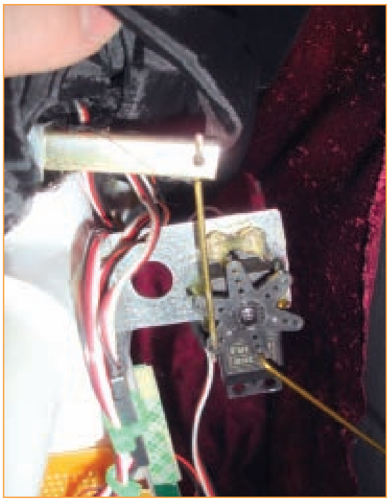
Vern's Six Servo Random Motion Program
www.spiderspreyground.com/howto/prop-1

Jon Williams Six Servo Code Optimization
www.efx-tek.com/php/smf/index.php?topic=675.0

EFX-TEK
www.efx-tek.com

International Association of Haunted Attractions
www.iahaweb.com

Professor Conrad
www.professorconrad.com



■ FIGURE 17. The second push-rod that makes the chest move forward when the chin lifts.

■ FIGURE 18. Kids get a chance to see how the Dungeon Keeper works at Armadillocon.

that it would be easier to just use a microcontroller to move the servos and use a random number generator to pick the target positions. This way, the character would stay in motion continuously (in a mostly unpredictable manner) without the necessity of programming all the actions. In addition, transferring control of the servos to a microcontroller eliminated the need to have a full Windows-based computer available whenever I wanted to operate the animatronic.

Lucky for me, about this time Jon Williams from Parallax had partnered with John Barrowman to create EFX-TEK, a company that was creating robust BASIC Stamp-based microcontrollers for use in the special effects and haunted house industry. I was lucky enough to get a prototype of the Prop-1 controller from Jon and John at Hauntcon in Dallas (**Figure 15**). I wrote some code that would allow the Prop-1 to cause six servo motors to move to random positions at random speeds. I made the software available for download from my website and gave Jon a copy that he then went on to optimize and release on the EFX-TEK website (also listed in Resources).

THE DUNGEON KEEPER AT HOME

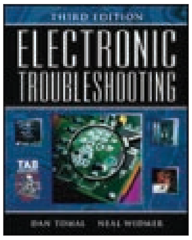
So, now that we had the Dungeon Keeper mounted in his new coffin (**Figure 16**), it made it very easy to upgrade and improve his operation. For starters, I added a connection from the head tilt servo to the back of the cabinet so when he lifted his head up, his chest would move forward (**Figure 17**). This allowed me to get two motions using a single servo. Next, I added a nice-sounding computer speaker system with a sub woofer and a portable CD-ROM player so I could trade out his sound tracks and dialog at any time (my daughter seems to think its incredibly funny to put Britney Spears CDs in the player). I made his right arm removable so the coffin can be closed up when he's not in use. Also, I pack a scrolling LED sign inside him as well, so that he can be used as an advertising system. The front of the coffin is removable so we often display him at events with all the covers off so folks can see how he works (**Figure 18**).

If you'd like to see The Dungeon Keeper in action, drop by my YouTube channel where videos of him in various performances will be available. If you end up building a Dungeon Keeper of your own, I would love to hear about it! Please feel free to email me at vern@txis.com. **NV**

We have over 170 related titles in our webstore!!

The Nuts & Volts WEBSTORE

"EDITOR'S PICKS"



Electronic Troubleshooting

Developing electronic troubleshooting skills can take years — or a few months with the proper resources at your fingertips. *Electronic Troubleshooting* is one of those resources. Not only does it provide a modest degree of handholding for readers new to the myriad test equipment available today, but the authors offer heuristics developed from their years of practical experience in the art of troubleshooting. This is a good book for beginners.

$49.95*

Save on Costly Repair Bills!

Troubleshooting and Repairing Major Appliances

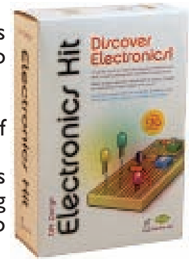
Given the modern economy, it pays to know how to repair everyday appliances, and this book provides an excellent overview of how to diagnose and repair everything from hot water heaters to microwave ovens. The book is highly illustrated, and the sections on safety and tool selection are especially helpful for first time do-it-yourselfers.

$59.95*

Editor Bryan Bergeron's recommended reads.
Find these and many more great titles in the *NUTS & VOLTS* Webstore!

ELECTRONIC NEWBIE

DIY Design Electronics Kit



This great kit contains everything you need to learn the basics of electronic circuit design. It contains all of the most common electronics components as well as a prototyping breadboard for you to get started right away.

The kit has over 130 parts!

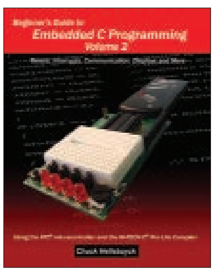
No soldering is required and the included 32 page illustrated manual guides you through each of the projects. After you build all of the projects, you can use the parts for your own designs.

NEW!

For a complete product detail, please visit: http://store.nutsvolts.com **$49.95***

ELECTRONICS

Beginner's Guide to Embedded C Programming Volume 2
by Chuck Hellebuyck



In this "Volume 2," Chuck takes the reader to the next level by introducing how to drive displays, how to use interrupts, how to use serial communication, and how to use the internal hardware peripherals of the PIC16F690 microcontroller such as SPI, PWM, and timers. When you have finished reading this book and completed the projects, you'll be well beyond the title of Beginner!

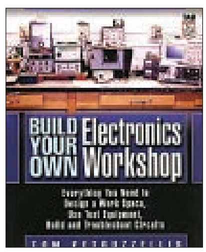
$39.95

The components that are added to the PICKit 2 that Chuck uses in his new book can also be purchased through the *Nuts & Volts* Webstore.

$12.95

Build Your Own Electronics Workshop
by Thomas Petruzzellis

YOUR DREAM ELECTRONICS LAB IS WAITING INSIDE!

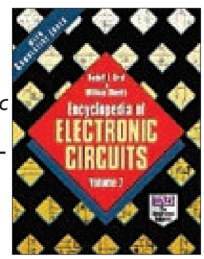


This value-packed resource provides everything needed to put together a fully functioning home electronics workshop! From finding space to stocking it with components to putting the shop into action — building, testing, and troubleshooting systems — popular electronics author Tom Petruzzellis' *Build Your Own Electronics Workshop* has it all! And the best part is, this book will save you money, big time!

Reg $29.95 Sale Price $24.95

Encyclopedia of Electronic Circuits, Volume 7
by Rudolf F. Graf / William Sheets

NEW IN THE BESTSELLING SERIES! ONE THOUSAND MORE LEADING-EDGE CIRCUIT DESIGNS!



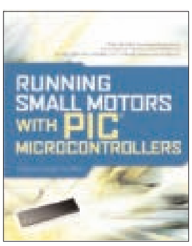
Designed for quick reference and on-the-job use, the *Encyclopedia of Electronic Circuits, Volume 7*, puts over 1,000 state-of-the-art electronic and integrated circuit designs at your fingertips. Organized alphabetically by circuit type, this all-new collection includes the latest designs from industry giants such as Advanced Micro Devices, Motorola, Teledyne, General Electric, and others.

$39.95

Running Small Motors with PIC Microcontrollers
by Harprit Singh Sandhu

NEW!

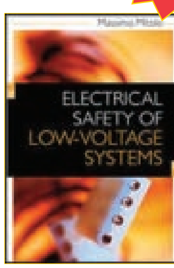
The only comprehensive guide to using PIC microcontrollers to drive small motors.



Running Small Motors with PIC Microcontrollers contains more than 2,000 lines of PICBASICPro code and dozens of circuit diagrams with the focus on controlling motors. Hands-on tutorials, program listings, and resources are included. **$29.95**

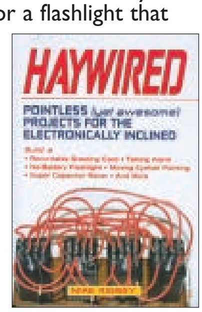
Electrical Safety of Low-Voltage Systems
by Massimo Mitolo

NEW!



Find all the information you need to minimize accident rates and ensure low-voltage system safety. *Electrical Safety of Low-Voltage Systems* offers you a comprehensive safety regimen, based on the fundamental characteristics of low-voltage electrical systems. Fully explains the grounding and bonding of low-voltage systems as they relate to article 250 of the National Electrical Code. **$89.95***

Haywired
by Mike Rigsby



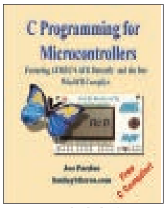
Construct a no-battery electric car toy that uses a super capacitor, or a flashlight that can be charged in minutes, then shines for 24 hours. Written for budding electronics hobbyists, author Mike Rigsby offers helpful hints on soldering, wire wrapping, and multimeter use. Each project is described in step-by-step detail with photographs and circuit diagrams. Includes websites listing, suppliers and part numbers.

$16.95

Order online @ www.nutsvolts.com

Or CALL 1-800-783-4624 today!

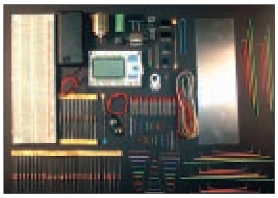
BOOK & KIT COMBOS



From the Smiley Workshop

C Programming for Microcontrollers

by Joe Pardue

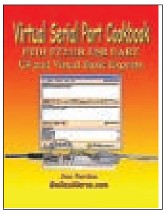


Book **$44.95**

Kit **$66.95**

Do you want a low cost way to learn C programming for microcontrollers? This 300 page book and software CD show you how to use ATMEL's AVR Butterfly board and the FREE WinAVR C compiler to make a veryinexpensive system for using C to develop microcontroller projects.

Combo Price $99.95 Plus S/H



Virtual Serial Port Cookbook

by Joe Pardue

As talked about in the

Nuts & Volts June issue,

"Long Live The Serial Port"

Kit **$69.95**

Book **$44.95**

This is a cookbook for communicating between a PC and a microcontroller using the FTDI FT232R USB UART IC. The book has lots of software and hardware examples. The code is in C# and Visual Basic Express allowing you to build graphical user interfaces and add serial port functions to create communications programs.

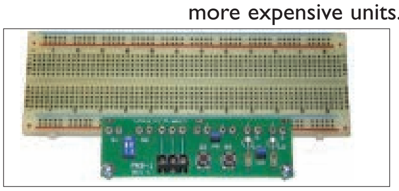
The Virtual Serial Port Parts Kit and CD

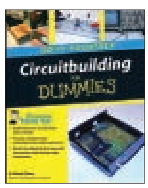
(also *available, above right*)

Reg. Price $ 114.90 **Subscriber Price $109.95 Plus S/H**

Proto Buddy Kit & Book Combo

For those just getting started in electronics as a hobby, a solderless breadboard (SBB) is the perfect platform for building those first circuits. Attach a Proto Buddy to an SBB, include a battery or two, and you will have a combo that has a lot of the same functionalities as more expensive units.





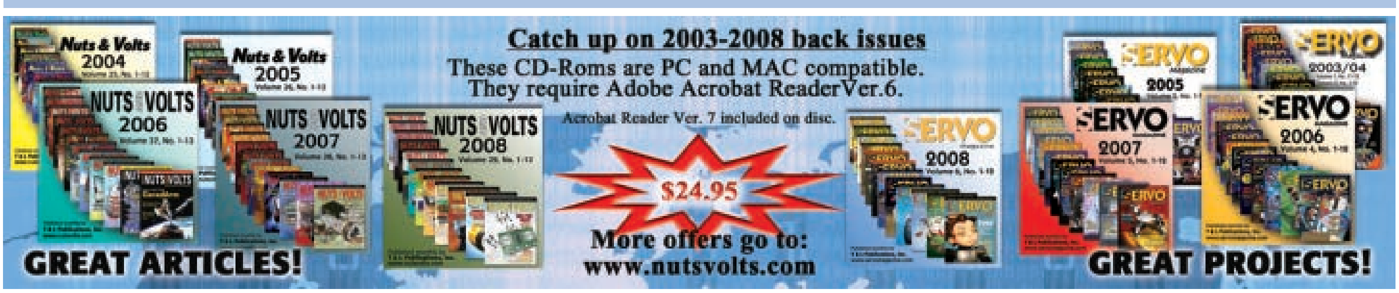
Combo includes PCB & Components, 830 point SBB, and *Do-it-Yourself Circuitbuilding For Dummies.*

Combo Price $57.95 Plus S/H

Limited time offer.

THE EVIL GENIUS SERIES

CD-ROMS

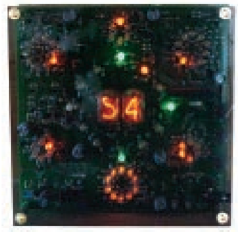


CALL 1-800-783-4624 today!
Or Order online @ www.nutsvolts.com

It's TIME to Build! PROJECTS

NixieNeon Clock Kit

NEW!




Using Neon and Nixie bulbs, this clock displays the precision movement of time and is programmable to display "Time Chaos" at different intervals. The NixieNeon Clock then resets itself to the correct time in an eye-catching ballet of luminosity.
The PCB is 7.25"x 7.25" and consists of over 400 components.

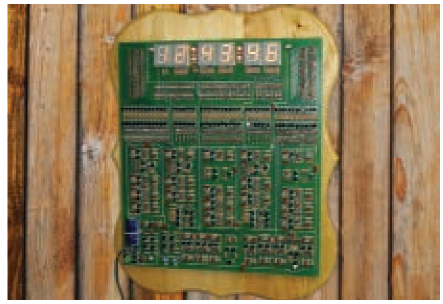
Subscriber's Price **$186.00**
Non-Subscriber's Price **$195.95**
PCBs can be bought separately.

Arch-Ball Clock PCB & MCU

This unique clock allows the hobbyist to be involved with a little wood working, as well as the electronics side of the project. We just supply you with the custom shaped printed circuit board and the programmed MCU. You'll have to go digging in your workshop for the other components and wood.

Subscriber's Price **$25.75**
Non-Subscriber's Price **$28.25**
Arch templates can be downloaded from the *Nuts & Volts* website.

Transistor Clock Kit

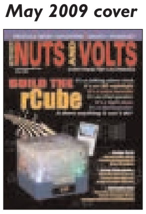


If you like electronic puzzles, then this kit is for you! There are no integrated circuits; all functionality is achieved using discrete transistor-diode logic. The PCB is 10"x11" and harbors more than 1,250 components!
For more info, see page 42, this issue.

Subscriber's Price **$214.95**
Non-Subscriber's Price **$225.95**
PCBs can be bought separately.

rCube Talking Alarm Clock KIt

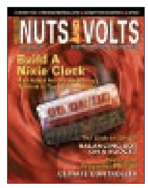
As seen on the May 2009 cover



Available in blue, black, red, and green. All components are pre-cut & pre-bent for easier assembly and the microcontrollers are pre-programmed with the software. Kits also include PCB, AC adapter, and instructions on CD-ROM.

Subscriber's Price **$49.95**
Non-Subscriber's Price **$54.00**
PCBs can be bought separately.

Nixie Tube Clock Kit



October 2006

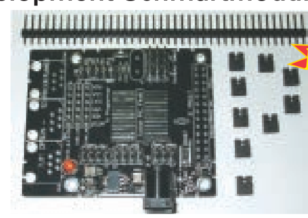
Nixie tube clocks fuse the spirit, drama, and eerie beauty of cold war technology with modern inner works to create uncommon handcrafted timepieces.

Now with optional case choices!
Get more info @
www.nutsvolts.com

Subscriber's Price **$146.95**
Non-Subscriber's Price **$159.95**
Kit includes article reprint, complete instructions and parts list.

8 Bit PIC® Microcontroller Development SchmartModule A

NEW!



This PIC Microcontroller Development board supports 116 different 8 bit SOIC PIC Microcontrollers. This board is fully populated except for the PIC. You hand-solder the PIC using the "EZ" technology from *Schmart Board*, configure the jumpers for your PIC part number, and start programming.
For more on "EZ" technology, please see this product in our webstore. **$14.95**

Big Ear Big Kit

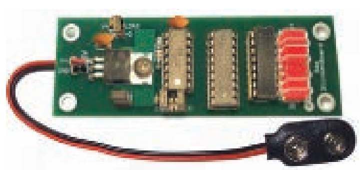
As seen on the December 2009 cover

Ever wish you could build an "audio telescope" that would let you hear things that were faint or far away? Then this kit is for you! Just follow along with the article and you will see how to put together your own "BIG EAR!"

Subscriber's Price **$98.95**
Non-Subscriber's Price **$111.95**
Kit Includes an article reprint.

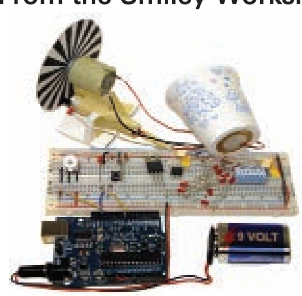
Das Blinkenboard Kit

This kit includes a preprogrammed ATtiny84 microcontroller that sports eight software PWM channels to control motor speed and light brightness. Jumper selectable patterns can be used to operate motors, solenoid valves, relays. Expand your board with GNU/GPL software updates to be featured in upcoming *NV* articles.



Subscriber's Price **$32.45**
Non-Subscriber's Price **$35.95**
PCBs can be bought separately.

Arduino Project Kit From the Smiley Workshop



Blink LEDs (Cylon Eyes). Read a button and 8-bit switch. Sense Voltage, Light, and Temperature. Make music on a piezo element. Sense edges and gray levels. Optically isolate voltages. Fade LED with PWM. Control motor speed and more.
$79.95

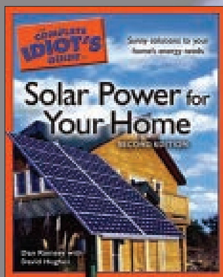
WE ACCEPT VISA, MC, AMEX, and DISCOVER. Prices do not include shipping and may be subject to change.

Attention **Subscribers ask about your discount on prices marked with an ***

The Nuts & Volts **WEBSTORE**

ALTERNATIVE ENERGY SECTION

The Complete Idiot's Guide to Solar Power for Your Home
by Dan Ramsey / David Hughes

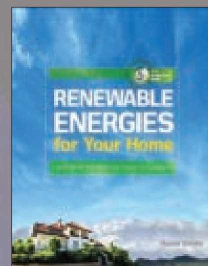


The perfect source for solar power — fully illustrated. This book helps readers understand the basics of solar power and other renewable energy sources, explore whether solar power makes sense for them, what their options are, and what's involved with installing various on- and off-grid systems. **$19.95**

Renewable Energies for Your Home
NEW!

by Russel Gehrke

Simple and Inexpensive Renewable Energy Solutions for Your Home.

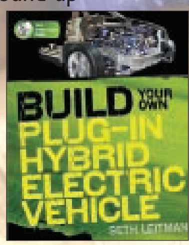


It's not always easy being green, and sometimes it costs more than you'd expect to get an eco-friendly home improvement project up and running. *Renewable Energies for Your Home* gives you sustainable home energy solutions that won't drain your wallet or the power grid. Filled with step-by-step instructions and helpful photos and illustrations. **$24.95**

Build Your Own Plug-In Hybrid Electric Vehicle
NEW!

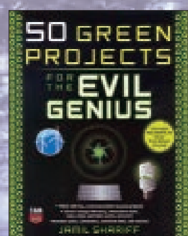
by Seth Leitman

A Step-by-Step Guide to Building a Plug-In Hybrid Electric Vehicle from the ground up



Build Your Own Plug-In Hybrid Electric Vehicle puts you in the driver's seat when it comes to hitting the road in a reliable, economical, and environmentally friendly ride. Inside, you'll find complete details on the hybrid powertrain and all the required components, including the motor, battery, and chassis. **$24.95**

50 Green Projects for the Evil Genius
by Jamil Shariff

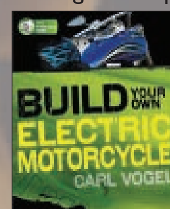


Using easy-to-find parts and tools, this do-it-yourself guide offers a wide variety of environmentally focused projects you can accomplish on your own. Topics covered include transportation, alternative fuels, solar, wind, and hydro power, home insulation, construction, and more. The projects in this unique guide range from easy to more complex and are designed to optimize your time and simplify your life! **$24.95**

Build Your Own Electric Motorcycle
NEW!

by Carl Vogel

A practical guide for building an electric motorcycle from the ground up.



Complete with hundreds of step-by-step pictures, charts, and graphs for the latest and most efficient technologies, this new TAB Green Guru Guide shows you how to build an electric motorcycle from scratch. Written by an electric vehicle expert, *Build Your Own Electric Motorcycle* provides current data on all required materials, components, and specifications. **$24.95**

SPECIAL OFFER

Making PIC Microcontroller Instruments and Controllers
by Harprit Sandhu

Harness the power of the PIC microcontroller unit with practical, common-sense instruction from an engineering expert. Through eight real-world projects, clear illustrations, and detailed schematics, *Making PIC Microcontroller Instruments and Controllers* shows you step-by-step how to design and build versatile PIC-based devices. **Reg $49.95**

Sale Price $42.95

CLASSIFIEDS

SURPLUS

SURPLUS ELECTRONIC PARTS & ACCESSORIES

Over 13,000 Items in Stock.

Cables, Connectors, Displays, Fans, Hardware, LEDs, Motors, Potentiometers, Relays, Semiconductors, Service Manuals, Speakers, Switches, Test Equipment, Tools, VCR Parts

Surplus Material Components
SMC ELECTRONICS
www.smcelectronics.com

No Minimum Order.
Credit Cards and PAYPAL Accepted.
Flat $4.95 per order USA Shipping.

COMPONENTS

RF PARTS™ CO.
Tubes, Transistors, Power Components
Email: rfp@rfparts.com • Web: www.rfparts.com
800-737-2787 Fax 888-744-1943

KITS/PLANS

QKITS.COM

50 AMP PWM
1-888-GO 4 KITS

Electronic Kits

- Fun and Educational
- Discount White and Blue LEDs
- Quantity Discounts

www.bakatronics.com

VIDEO AGC/SYNC PROCESSING PROJECT
AVR RISC Microcontroller-Based
Instruction Manual CD's
Printed Circuit Boards
Pre-programmed Microcontrollers
Free Patent Application Information
www.jlkelectronics.com

Did you know that if you're a paid subscriber to *Nuts & Volts*, you can get the online version for *FREE*? Go to www.nutsvolts.com.

Brilldea
purveyor of prototyping goods
+RGB LED Ribbon
+RGB LED Pixels
+LED Painter
+Parallax Propeller
+LED Lumen
+3.0" LCD w/ composite video input
www.brilldea.com

uM-FPU V3.1
Floating Point Coprocessor

32-bit IEEE 754
SPI or I2C
DIP-18, SOIC-18

Fast – Easy to Use
Extensive floating point support, GPS input, FFT, 12-bit A/D, matrix operations, user-defined functions.
www.micromegacorp.com

LEDs
Super Brights from 20¢
RGB Color Mixing 30 Pack $6.99
Assortment 120 Pack $24.99
Shipping from $3.00
Alan-Parekh.com/Store

Nixie Power

2-16V In, 4-8W / 150-200VDC Out
0.95" x 0.95" x 0.35"
$9.95 (Shipping included)
www.tayloredge.com/nixie

SCSI
I-U320 50Pin-68Pin-80Pin
1 to 8 Bay Case Enclosures
Adapters Cables Terminators
Low Prices - Qty Discounts!
(Also FireWire, USB, Video)
www.mcpb.com

SOLAR PRODUCTS/KITS

BATTERY DESULFATORS
www.wizbangplus.com

MISCELLANEOUS FOR SALE

WANT TO BUY ...
Electronic distributing or manufacturing company
Anything considered. Inventory, equipment, fixtures, entire company. Call ISE at no cost or obligation.
PH: 956-444-0004 (toll free) 888-351-5550
tommy@iseliquidator.com

BOOKS

Books

PIC® Microcontroller
sq-1.com

Stepper Motors
stepperstuff.com

CNC
cncintro.com

SQUARE 1 ELECTRONICS
(208) 664-4115
Hayden, ID USA

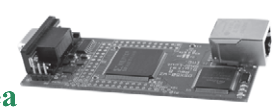
www.servomagazine.com

MICROCONTROLLERS

World Leaders in Win/Mac/Linux Driver-Free USB Chips!
- USB-232/USB-SPI/USB-I2C serial bridges
- USB-FileSys flash drive with SPI interface
- TEAleaf-USB authentication dongle
- USB-DAQ data logging flash drive
- expandIO-USB for PC-driven I/O
- Buy from Digikey, Mouser, Farnell

expandIO-USB · USB · PC · USB Status · A/D-I/O-SPI-I2C
HexWax Ltd - www.hexwax.com

DigitalShortcut.com *"Web servers for everybody"*
Xilinx Spartan3AN + W5300 or LPC2148 +W5300
– easily add 100 Mbit/s Ethernet to almost anything
– solid, easy to comprehend hardwired TCP/IP stack from WIZnet, 128kB of network buffers
– free tools, fast demo http server included



Development platforms $87/ea

www.nutsvolts.com

HARDWARE WANTED

DEC EQUIPMENT WANTED!!!
Digital Equipment Corp. and compatibles.
Buy - Sell - Trade
Call Keyways 937-847-2300
or email buyer@keyways.com

WANTED
used - surplus - obsolete
radios, tvs, capacitors, inductors
transistors, RF parts, meters, dials
heatsinks, switches, transformers
antennas, test equipment, crystals
tubes, connectors, motors, manuals
www.SecondHandRadio.com

MicroStamp11
World's Smallest 68HC11 Microcontroller Module!

- *telemetry*
- *smart toys*
- *animatronics*
- *microrobotics*
- *model railroading*
- *home automation*

Ideal for college and hobby projects!

- tiny, light-weight module
- choice of 8K or 32K EEPROM
- SCI, SPI, pulse accumulator
- generate pulses, PWM, etc.
- measure time, frequency, etc.
- 14 digital I/O lines + interrupts
- use Assembler, BASIC, or C
- lots of code examples/tutorials
- easy Windows code-loading
- Starter Packages from $49

www.MicroStamp11.com

FEEDBACK

continued from page 11

operated now, it is the easy way out to assume that a software or firmware upgrade will straighten out any shortcomings later. Interestingly, one of the few areas that I was on the cutting edge was wristwatches. When the LED digital wristwatches first were introduced, I got one. Not so much for the novelty, but for the decreased weight and the fact that I have the uncanny ability to destroy a mechanical wristwatch in a year or less ... doesn't matter whether it's Omega or Timex. The LED digital offered solid-state construction. Big surprise that the battery drain was atrocious and I spent a lot on batteries the first year. Fast forward 30 years or so. I have only had about five wristwatches in that time — all digital. They have proved to be durable, astoundingly accurate, and easy on the batteries. And, of course, the features increased exponentially. But it took about 10 years to get there. I am very satisfied with this mature technology. Otherwise, I still don't have a cell phone, just moved from dial-up to broadband, am resisting digital television, and just started to explore digital radio modes that have been round for 10 or 15 years. Why do I read *Nuts & Volts*? So that when I am forced into a new technology, I at least know what everybody is talking about!

Tom Wilbeck, N5KGN
Longview, TX

Thanks for the feedback. I think we have a similar take on things. I had an LED watch when they were first introduced (purchased with all of my savings in high school). I believe in market forces more than technology push (I teach a course on innovation/business at Harvard/MIT), and I'm not an early adopter — more of an early sampler so as not to be burned. I hope that many readers will resonate with your thoughts.

Bryan Bergeron, NU1N

DELIGHT IN DC-TO-DC

Regarding Jim Stewart's article entitled "Wind Your Own Transformer and Build a DC-DC Converter" in the March '09 issue. I started designing DC-to-DC converters in 1972 and I've read lots of technical documentation on transformers including the 1943 MIT Press edition by that name. I wish that I could have seen an article like Mr. Stewart's when I started. It is very well written, lucid, and logical without over-stressing the technological issues; particularly the non-linearity of magnetic circuits. I think that it beautifully accomplished the intended purpose — that of encouraging a beginner to try winding his/her own high frequency power transformer.

A few things that I'd add as an addendum:

* If the user wants to wind a mains-frequency transformer, he/she needs to use a laminated iron core.

* The turns-per-volt equation assumes square wave input. The T/V equation is overly generous (although it will certainly work) because the area under a sine waveform — and thus the magnetic flux build-up per half-cycle — is less than that of a square waveform of similar amplitude.

* For high-frequency transformers, care must be taken to minimize leakage inductance, particularly for high frequency transformers. You could rephrase that as maximizing the coupling between the primary and secondary windings. I learned that lesson during a development project the hard way. I noted that you wound the secondary winding onto the core before winding the primary winding — which is good practice — but you might indicate WHY you did that. Furthermore, if there are to be multiple secondaries, the secondary winding providing the greatest power should be the first one wound on the core.

* Several other applications for the simple circuitry that Jim used suggest themselves, in particular, power to operate vacuum-fluorescent or gas-discharge displays. The former needs filament voltage (can be AC) and about 30 volts DC for the electrode voltages; the latter needs about 220 VDC at minuscule current.

Peter A. Goodwin
Rockport, MA

TECH FORUM

This is a READER-TO-READER Column.

All questions *AND* answers are submitted by *Nuts & Volts* readers and are intended to promote the exchange of ideas and provide assistance for solving problems of a technical nature. Questions are subject to editing and will be published on a space available basis if deemed suitable by the publisher. Answers are submitted by readers and NO GUARANTEES WHATSOEVER are made by the publisher. The implementation of any answer printed in this column may require varying degrees of technical experience and should only be attempted by qualified individuals. Always use common sense and good judgement!

All questions and answers should be sent by email to forum@nutsvolts.com All *diagrams should be computer generated and sent with your submission as an attachment.*

QUESTIONS

To be considered, all questions should relate to one or more of the following:

1. Circuit Design
2. Electronic Theory
3. Problem Solving
4. Other Similar Topics

- Be brief but include all pertinent information. If no one knows what you're asking, you won't get any response (and we probably won't print it either).
- Include your Name, Address, Phone Number, and email. Only your Name, City, and State will be published with the question, but we may need to contact you.
- No questions will be accepted that offer equipment for sale or equipment wanted to buy.
- Selected questions will be printed one time on a space available basis.
- Questions are subject to editing.

ANSWERS

- Include in the subject line of your email, the question number that appears directly below the question you are responding to.
- Payment of $25.00 will be sent if your answer is printed. Be sure to include your mailing address or we cannot send payment.
- Only your Name, City, and State, will be printed, unless you say otherwise. If you want your email address included, indicate to that effect.
- Comments regarding answers printed in this column may be printed in the Reader Feedback section if space allows.

>>> QUESTIONS

Battery Charging

I have a door access control system that uses 110 VAC normally but has a 7 Ah battery for backup power. This only offers a very short time period of battery power should the AC fail. Its built-in power supply/charger is rated at 1A. My question is, what are the rammifications of substituting a much larger battery for the 7 Ah one? Aside from the possibility that once depleted, a higher amp hour battery would take longer to recharge and possibly not even recharge fully, are there any other detrimental possibilities to the system or the battery?

#9091 **S. Miller**
Encinitas, CA

Antenna Coupling

I want to couple a 470-490 MHz Yagi and a wide band omnidirectional antenna together and use a single run of coax into my house. Can I simply use a coax tee connector?

#9092 **Chris Karnow**
Hopewell Junction, NY

Current Source

I understand that you can use a voltage regulator to work as a current source. Is there a limitation on the load that the current will pass through? I would like to pass the current through a platinum temperature sensor and a fixed resistor of known value to determine the temperature of the sensor. The current suggested is between 0.1 and 1.0 mA to avoid self heating. If the fixed resistor has a value of 10,000 ohms and I have a current of 0.5 mA, then the voltage drop across the resistor is 5.0 volts. Would this mean that I would need a power source greater than the voltage drop across the resistance plus the voltage output of the regulator?

#9093 **Lance Corey**
Fullerton, CA

LED Ramp Up

I need a very basic schematic that will slowly ramp up an LED from minimum brightness to full and back. This is for the transmission towers on my model train table. By the way, thanks for the under track sensor schematic published in a previous month.

#9094 **Bailey Pendergrass, Jr.**
Oakland, CA

Drill Charger

I have several battery powered drills, 12.5V through 19.5V. Most of the charging stations are minimal at best, only lasting a few months. Does anyone have a good schematic for a battery charger that can charge any of the drill batteries up to and including the 19.5V battery?

#9095 **Bailey Pendergrass, Jr.**
Oakland, CA

>>> ANSWERS

[#4095 - April 2009]
Digital TV Conversion

Has someone come up with a design for a digital TV converter which can be programmed like a VCR for taping when I'm not around?

Ideally, it would support two lines: one for the VCR and one for the TV.

#1 There are at least two coupon eligible DTV converters available that have event timers. Dish Network (Echostar) makes one sold under two different names: DTV Pal and TR-40. The Zinwell ZAT-970A DTV converter also has an event timer. Either of these units allow at least eight events to be programmed. A programmed event will turn on the DTV converter — if not already on — and set the channel. The recorder will still need to have its own timer programmed. An Internet search should find many stores selling these converters.

Michael Radtke
Phoenix, AZ

#2 The easiest way to implement this is to use a PC with a USB NTSC/ATSC HDTV receiver and an external USB large hard drive. I use a laptop with a Hauppauge WinTV-HVR-950 receiver to record HDTV content to the internal hard disk. The good thing about this arrangement is size, since the receiver is only about 2" long, 1/2" thick, and 1" wide. It came with its own 4" antenna and application (XP and Vista). You will need a good HD capable video card with the correct output: component, DVI, or HDMI to connect to your HDTV. There are also internal TV receiver cards available and you can run more than one card in one PC, as long as the PC has enough resources available. The receiver will also digitize old analog content through S-video or composite (yellow, white, red RCA connectors). 1080i content uses a lot of disk space — 5.8 GB per hour — so a large hard disk is recommended. Even an older Pentium 4 or Athlon XP with more than 2 GHz should work well with one card.

Walter Heissenberger
Hancock, NH

[#4096 - April 2009]
LM3915 Setup

I'm trying to build an LED display to show the position of a remote arm. I am using the LM3915 in the dot mode to drive the 10 LEDs. The voltage divider to establish the position of the arm is my problem. I have linked a 10K pot to the arm via a direct link. The arm moves the pot about 90-100 degrees of its travel limits.

This unit is being powered by 12V which is also available for use in the power divider circuit for the input. I have placed in series with the 10K pot another 5K pot as a method to refine the scale of the output. I've had no luck setting it up so that when the arm is at one limit, the #1 LED is on and when at the other limit (approx. 95 deg of travel on the pot), the #10 LED is on. I would also like the display LEDs to be adjustable in brightness, as well.

Actually a better choice for this project would be the LM3914 since it has a linear voltage reference. Either way though, the reference for the chip needs to match the voltage from the sensing pot. Since the control arm has about 95 degrees of travel or about 1/3 of the pot that should correspond to approx. four volts using a 12 volt supply and a linear pot. **Figure 1** is a simple modification of the stock datasheet to accommodate those parameters.

To calibrate, set the remote arm to #1 position, adjust R4 for zero output, and connect the pot via the mechanical link. Set R1 for zero ohms. Move the arm to the #10 position and adjust R2 until just the #10 LED lights. Move the arm back to the #1 position and adjust R1 until just the #1 LED lights. You will probably have to make these adjustments several times to fine tune. R3 is used to vary the brightness of the LEDs from 2 to 15 mA with the values shown. This circuit has been tested using the LM3914 and a regulated 12 volt supply.

Steve Ghioto
Neptune Beach, FL

[#4097 - April 2009]

Is there an up-to-date schematic or project to convert RGB or Composite video signals to VGA (or SVGA, XGA, etc.) and vice versa? I'd like to incorporate this into a few home projects. I don't want to buy one, just build one!

I know you'd rather build one, but the circuitry required to convert RGB or VGA to Composite and back is very complicated, and the cost of a kit would probably be much higher than buying a commercial device. Try **www.tigerdirect.com** or **www.ramelectronics.net**. They both sell this kind of equipment as do many others. For example, TigerDirect has the Star Tech COMP2VGA which converts composite to VGA and costs about $65. Ramelectronics has the GEZ-1000 VGA-to-Composite converter which converts VGA to Composite and also to S-Video, and

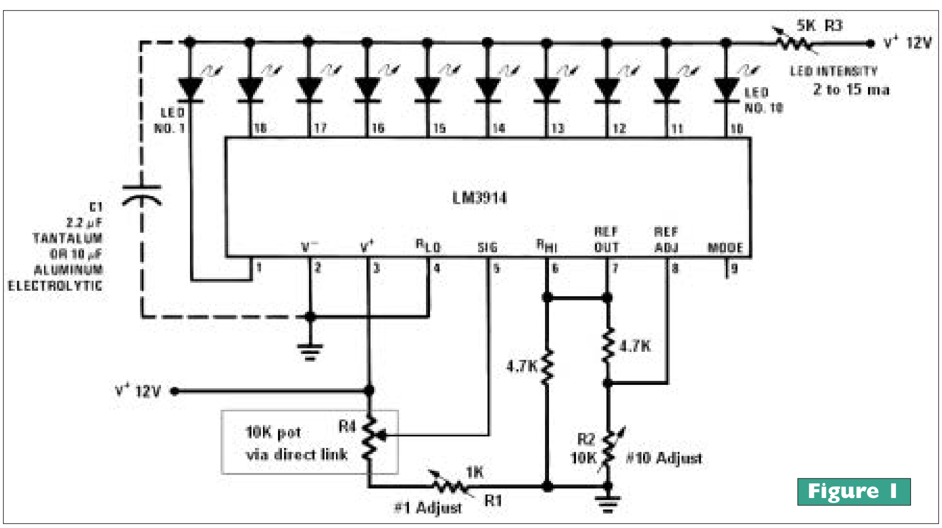


Figure 1

costs about $45. **Newegg.com** sells similar equipment, and you probably can also find this kind of thing on eBay. If you have a newer HDTV, check to see if it has a VGA or DVI input on the back — most do. You could then connect your computer's VGA output to the HDTV up to 1920x1080 using the TV as a VGA-to-TV converter.

Mark Lewus
Denville, NJ

[#5091 - May 2009]
Mylar Speakers

I would like to get information on Mylar speakers and their theory of operation. I need to replace a Mylar speaker installed in a Panasonic cordless handset telephone. Can a regular dynamic speaker replace a Mylar?

A regular dynamic speaker can replace a Mylar speaker. Mylar speakers are typically used where there is a chance that the speaker may get wet. A cordless telephone has a good chance of getting water on the speaker either due to use outdoors or perspiration. A regular paper speaker would be damaged by dampness. As long as the paper speaker is the same physical size, has close to the same impedance, and power rating, it will work fine. The main thing to look for to use in a cordless phone will be to find a speaker small enough to fit.

I have used surplus speakers found at advertisers in *Nuts & Volts* in the past to replace small speakers. Two good sources are All Electronics and Mouser Electronics, (both current advertisers in *Nuts & Volts*.)

E. Kirk Ellis, KI4RK
Pikeville, NC

[#5092 - May 2009]
PIR Motion Detector

I purchased an inexpensive PIR motion detector and did not notice it said "for incandescent only" in small print. It works great with an incandescent lamp, but not well with an inductive load such as a relay or fluorescent lamp. Is it feasible to alter one of these to operate other loads? If so, how?

#1 For your consideration — keep the incandescent bulb attached to the motion detector. Attach a CdS (Cadmium Sulfide) photocell to the bulb or, for faster response, a phototransistor that's connected to a one or two transistor amplifier. The amp can power whatever you want. The photocell/transistor can be attached to the bulb with several layers of electrical tape or in a small tube to contain the light. In this way, the bulb can be changed out when necessary — it's incandescent! This is a cheap optocoupler. An incandescent bulb works well with both A/C and D/C. If the detector's output is D/C, you can splice in a regular optocoupler in place of the bulb and go from there.

Phillip Potter
Pomona, CA

#2 It sounds like the PIR module contains a TRIAC which switches the AC load; although other circuitry is possible. A TRIAC driving an inductive load often has a snubber connected between MT1 and MT2 (main terminal 1 and main terminal 2) to aid in commutation — turning off. The snubber is a 0.1µF 400V capacitor in series with a 100Ω to 220Ω 1/2 watt resistor. If the PIR says "incandescent only," it may be missing the snubber.

If you do not want to open the module, consider having the PIR drive a solid-state relay (SSR), 120 VAC triggered version. It looks like a 33KΩ resistive load. Consider an AC input SSR like the OPTO 120A10. (See **www.opto22.com/**). This SSR has an AC pickup voltage of 80 VAC (280 VAC allowable). Dropout is 10 VAC. The 12A10 handles 10 amps and has a snubber built in. When shopping for an SSR, be sure that the input side handles 120 VAC.

Dennis Crunkilton
Abilene, TX

[#5093 - May 2009]
DC Power Transformer Question

I have five table-top water fountains which I want to run constantly. They are designed to use two AA batteries for each fountain, which is impractical.

***1.** What plug-in DC power transformer (voltage and amps) can I substitute for the 10 batteries to power all five devices?*

***2.** How should it be wired — in series or parallel?*

#1 Assuming that your pumps have been designed to run from industrial AA alkaline cells of 2,100 mA capacity, we can guesstimate the current draw as not exceeding C/10 (capacity) of the cell: 2,100 mA/10 Hr = 210 mAh. The 210 mAh is an upper limit for the current draw if your pumps run for at least 10 hours. You have two choices: **1)** run your five 3V motors in series from a 3x5 = 15 VDC supply; or **2)** parallel them across a (difficult to find) 3V supply.

1) *NV* advertiser All Electronics has a 15V 1A supply CAT# PS-151 for $8.75. Test this five-in-series configuration out first on a spare 12 VDC supply, or 12V gel cell borrowed from an alarm or a UPS. The motors will run a little slower, receiving 12.6/5 = 2.52V instead of 3V. If the test proves promising, spring for the 15V supply for a more vigorous fountain.

2) One advantage of the 3V supply is that the motors may be individually switched on. Also, use this approach if the pumps are not identical, or are not loaded equally. The bad news is that you need 5 x 210 mA = 2,100 mA = 2.1A of current. *NV* advertiser Jameco has a 3V 4A supply; stock #19228863 for $14.95.

Dennis Crunkilton
Abilene, TX

#2 For an off-the-shelf, inexpensive solution to operating your table-top water fountains, I went to **www.allelectronics.com**; $5.75 plus shipping.

1. Use the following parts: Catalog # PS-537, 5 VDC 3.7A switching power supply for $4.75.

Add three diodes in series with the output. This will drop the voltage from 5 VDC to about 3 VDC. If the fountains don't run fast enough, simply delete one of the diodes. A suitable diode is also available from All Electronics; four for $1.00, catalog P600K. It's rated to handle six amps.

2. Wire your fountains in parallel, each one across the power supply.

E. Kirk Ellis
Pikeville, NC

AD INDEX

Economy 1U & 2U 19" Rack Mount Chassis with Aluminum front panels

Thease chassis are shipped assembled The Black Anodized Aluminum Front Panel comes pre-drilled for easy rack mounting on to a standard 19" Rack. The steel chassis is painted black.

NEW ITEM

Item#	37-1U	37-2U
Front Panel Dimensions	485 mm x 44 mm 19.09in x 3.46in	485mm x 88mm 16.92in x / 19.09in x 11.81
Outside Dimensions	430mm x 300mm x 44mm 16.92in x 11.81in x 1.73	443mm x 300mm x 83mm 17.44in x 11.81in x 3.26in
Inside Dimensions	425mm x 295mm x 35mm 16.73in x 11.61in x 1.37in	435mm x 295mm x 80mm 17.12in x 11.61in x 3.14in
Price	$34.95 ea.	$39.95 ea.

ESD Safe, CPU Controlled, SMD Hot Air Rework Station

What every shop or lab needs to deal with todays SMD designed circuit boards. OEM manufactured just for Circuit Specialists Inc., so we can offer the best price possible! A multi-technology assembly and repair station. A wide selection of nozzles are also available.

- CPU Controlled
- Built-in vacuum parts handling wand
- Air Pump: Diaphragm special-purpose lathe pump
- Capability: 23L/min (Max)
- Temperature Range: 100°C~480°C/212°F~896°F
- 15-Minute Stand-By temperature "sleep" mode
- Power:110/120 VAC, 320 W maximum

Item # CSI825A++

$99.00

Big Sale! Inventory Reduction

One Dollar Upgrade !!

Wow! Now thats a lot for only a Dollar more!!

You get the CSI2205D DMM prefitted into our 45-1 Protective Case for only one dollar more than the price of the CSI2205D alone.

The CSI2205D Micro Control Unit auto-ranging DMM is designed for measuring resistance, capacitance, DC & True RMS AC voltage, DC & True RMS AC current, frequency, duty cycle and temperature, along with the ability to test diodes, transistors and continuity.
Regular Price $59.00

The 45-1 case is ideal for transporting small electronics & other delicate items.
Regular Price $29.00

$88.00 if purchased Seperatly!
Save $28.00!!!

Item# CSI2205D-BUNDLE **$60.00**

3 in 1 FOCUSED Infrared Soldering/Repair System

The CSI720 Three in One Focused Infrared Welding System generates heat through a concentrated infrared heat wave, providing precise soldering without movement of surrounding components.

ESD Safe, Focused Infrared Welding Station
For reworking BGAs, micro BGAs, QFPs, PLCCs, SOICs, small SMD and other circuit board components. Unit produces a concentrated infrared heat wave, for precision soldering. Infrared soldering eliminates movement of surrounding components, and marks on reworked PCB's, both associated with standard hot air gun reworking.
3 in 1 Repairing System
Combines the function of an Infrared Welding Tool, Soldering Iron and Pre-heater.
Full Digital Control with LED Displays
Allows precision setting of welding temperature & time, soldering iron and pre-heating temperatures.
Closed loop temperature control
For instant and precise process adjustments.
Adjustable Infrared Tool Post
Stable and adjustable Infrared welding tool holder for increased precision soldering and hands free operation.
Adjustable Eye shield & Welding Goggles
To protect users from harmful light rays.

Uses infrared heat wave technology instead of the conventional hot air, effectively solves the major problem being encountered when using the hot air gun, which is the movement of surrounding components while reworking.

Item # CSI720 **$1,399.99**

60MHz Hand Held Scopemeter with Oscilloscope & DMM Functions

Who Says you can't take it with you?
With the DSO1060 YOU CAN!

You get both a 60 MHz Oscilloscope and a multi function digital multimeter, all in one convenient lightweight rechargeable battery powered package. This power packed package comes complete with scopemeter, test leeds, two scope probes, charger, PC software, USB cable and a convenient nylon carrying case.

NEW ITEM

- 60MHz Handheld Digital Scopemeter with integrated Digital Multimeter Support
- 60MHz Bandwidth with 2 Channels
- 150MSa/s Real-Time Sampling Rate
- 50Gsa/s Equivalent-Time Sample Rating
- 6,000-Count DMM resolution with AC/DC at 600V/800V, 10A
- Large 5.7 inch TFT Color LCD Display
- USB Host/Device 2.0 full-speed interface connectivity
- Multi Language Support
- Battery Power Operation (Installed)

Item # DSO1060 **$549.00**

ESD Safe SMD & Thru-Hole Rework Station

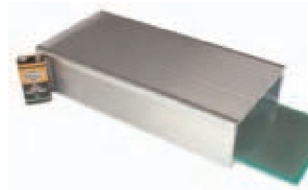
An SMD rework station & soldering station in one handy unit! Perfect for shops & labs dealing with todays SMD board designs. Comes with an ESD safe soldering iron and a Hot Air Wand with 3 Hot Air Nozzles. A wide range of nozzles are also available.

Big Sale! Inventory Reduction

Item # CSI906 **$99.00**

Extruded Aluminum Enclosures with Fitted Perfboards inclued

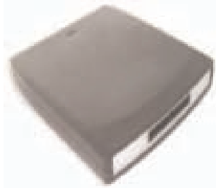
These attractive cases are made of extruded polished aluminum with internal slots that can accommodate 2 PCBs up to 0.08" thick. Mounting tabs at each end aid in securing the box to a surface. One PCB is included with each enclosure (2nd PCB optional).



NEW ITEM

Item # 17-10A	Item # 17-10B	Item # 17-10C
Outside Dimensions 70 x 32.5 x 152.4 mm 2.75 x 1.27 x 6 in	Outside Dimensions 80 x 37.5 x 179 mm 3.14 x 1.47 x 7.04 in	Outside Dimensions 100 x 47.5 x 203 mm 3.93 x 1.87 x 7.99 in
Inside Dimensions 55 x 25 x 152.4 mm 2.16 x 0.98 x 6 in	Inside Dimensions 65 x 30 x 179 mm 2.55 x 1.18 x 7.04 in	Inside Dimensions 85 x 40 x 203 mm 3.34 x 1.57 x 7.98 in
PCB Size 50 x 20 x 152 mm 1.95 x 0.78 x 5.98 in	PCB Size 60 x 25 x 179 mm 2.36 x 0.98 x 7.04in	PCB Size 80 x 35 x 203 mm 3.14 x 1.37 x 3.98 in
Perfboard Specifications 20 x 57 plated thru holes on 0.1in centers on double-sided FR-4 board	Perfboard Specifications 24 x 67 plated thru holes on 0.1in centers on double-sided FR-4 board	Perfboard Specifications 32 x 77 plated thru holes on 0.1in centers on double-sided FR-4 board
1+ $9.95 10+ $8.49	1+ $12.95 10+ $10.50	1+ $14.95 10+ $13.95

34 Channel USB Logic Analyzer



The CSI5034 is a sophisticated, portable, and easy-to-use 500MHz, 34-channel logic analyzer equipped with features found only in more expensive bench type instruments.

Using advanced large-scale integrated circuits, integrated USB 2.0, CPLD, FPGA, high-frequency digital circuitry, embedded systems, and other advanced technology, make the CSI5034 your best choice in pc-based logic analyzers The CSI5034 is suitable for electronic measurement engineers, college students in scientific research and development and teaching assistants.

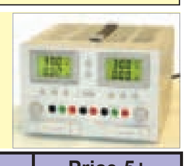
- 34 input channels capable of simultaneously monitoring data and control information, and is capable of capturing narrow pulses and glitches that may be missed by other test equipment.
- Delay feature provides the ability to capture data around the waveform, both before and after the desired trigger signal. This allows the operator to view the data at multiple points in the data stream
- Memory feature stores multiple data points for error analysis of the unit under test and to aid in locating defective components.
- Intuitive and flexible viewing screens to facilitate analysis of the system under test. Data can de displayed as binary, decimal, or hexadecimal values.
- Can be triggered in a variety of ways (rising edge, falling, edge or both) , and also has an advanced trigger function that allows logic operations to be performed on the data before a trigger is generated. This provides the ability to trigger on a specific data byte or word from any of the monitored channels.

NEW ITEM

Item # CSI5034 **$329.00**

Triple Output DC Bench Power Supplies

- Output: 0-30VDC x 2 @ 3 or 5 Amps & 1fixed output @ 5VDC@3A
- Stepped Current: 30mA +/- 1mA



Item #:	Price 1-4	Price 5+
CSI3003X3 0-30Vx2@3A	$198.00	$193.00
CSI3005XIII 0-30Vx2@5A	$259.00	$244.00

Premium All-In-One Repairing Solder System

The BlackJack SolderWerks BK6000 Repairing System is a digital multipurpose reworking system that incorporates a Hot-Air Gun, Soldering Iron, (compatible with leaded solder or lead free solder), with integrated smoke absorber and a desoldering Gun.

Item# BK6000 **$199.00**

Hot Air System w Soldering Iron & Mechanical Arm

The BK5000 from BlackJack SolderWerks provides a very convenient combination of hot air & soldering in one compact package. The hot air gun is equipped with a hot air protection system providing system cool down & overheat protection.

Item# BK5000 **$119.00**

Hot Air with Vacuum I.C. handler & Mechanical Arm

The BlackJack SolderWerks BK4050 is designed to easily repair surface mount devices. Its digital display & tactile buttons allows easy operation & adjustments. The BK4050 includes a hot air gun and a vacuum style I.C. handler.

Item# BK4050 **$119.00**

Thermostatically controlled desoldering station

The BlackJack SolderWerks BK4000 is a thermostatically controlled desoldering station that provides low cost and solid performance to fit the needs of the hobbyist and light duty user. Comes with a lightweight desoldering gun.

Item# BK4000 **$119.00**

Digital Display Solder Station for Lead Free Solder

The BK3000LF is a compact unit designed to be used with lead free solder that provides reliable performance featuring microprocessor control and digital LED temperature display. A wide range of replacement tips are available.

Item# BK3000LF **$74.95**

Compact Digital Display Solder Station

The BK2000+ is a compact unit that provides reliable soldering performance featuring microprocessor control and digital LED temperature display. A wide range of replacement tips are available.

Item# BK2000+ **$56.95**

Compact Soldering Station

The BlackJack SolderWerks BK2000 is a compact unit that provides reliable soldering performance with a very low price. Similar units from other manufacturers can cost twice as much. A wide range of replacement tips are available.

Item# BK2000 **$36.95**

MG Chemicals Solder

M.G. Chemicals Rosin Activated Flux formula is used in our flux-cored Solder Wire. Its rapid wetting and fast flowing properties results in consistent and reliable soldering every time. Cleaning becomes optional with our RA Flux core because of its non-corrosive and electrically non-conductive properties.

60% tin / 40% lead

0.062" 16 Gauge 1 lb (4898-454G) **$18.95**
0.062" 16 Gauge 1/2 lb (4898-227G) **$9.95**
0.050" 18 Gauge 1 lb (4897-454G) **$19.35**
0.050" 18 Gauge 1/2 lb (4897-227G) **$10.45**
0.040" 20 Gauge 1 lb (4896-454G) **$19.35**
0.040" 20 Gauge 1/2 lb (4896-227G) **$10.45**
0.032" 22 Gauge 1 lb (4895-454G) **$15.90**
0.032" 22 Gauge 1/2 lb (4895-227G) **$10.45**
0.025" 23 Gauge 1 lb (4894-454G) **$19.35**
0.025" 23 Gauge 1/2 lb (4894-227G) **$10.45**

63% tin / 37% lead

0.062" 16 Gauge 1 lb (4888-454G) **$18.95**
0.062" 16 Gauge 1/2 lb (4888-227G) **$9.95**
0.050" 18 Gauge 1 lb (4887-454G) **$19.35**
0.050" 18 Gauge 1/2 lb (4887-227G) **$10.45**
0.040" 20 Gauge 1 lb (4886-454G) **$19.35**
0.040" 20 Gauge 1/2 lb (4886-227G) **$10.45**
0.032" 22 Gauge 1 lb (4885-454G) **$15.90**
0.032" 22 Gauge 1/2 lb (4885-227G) **$10.45**
0.025" 23 Gauge 1 lb (4884-454G) **$19.35**
0.025" 23 Gauge 1/2 lb (4884-227G) **$10.45**

M.G. Chemicals No Clean formula uses synthetically refined resin and an effective activator. Our No Clean formula wets and spreads like normal RA type flux and does not splatter.

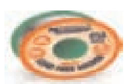
60% tin / 40% lead

0.032" 22 Gauge 1 lb No Clean (4875-454G) **$19.35**
0.032" 22 Gauge 1/2 lb No Clean (4875-227G) **$10.45**

63% tin / 37% lead

0.032" 22 Gague 1 lb No Clean (4865-454G) **$19.35**
0.032" 22 Gague 1/2 lb No Clean (4865-227G) **$10.45**

Lead Free Solder



M.G. Chemicals no clean Lead-Free Solder was designed with Sn/Cu (Tin/Copper) alloys as a lead-free alternative for the standard Tin and Lead solder. These alloys conform to the impurity requirements of J-Std-006 and RoHS. Use this solder anywhere you would use normal solder.

96.3% tin / 0.7% copper and 3% silver

.032" 21 Guage - No Clean 1/4lb (4900-112G) **$11.80**
.032" 21 Guage - No Clean 1/2lb (4900-227G) **$22.94**
.032" 21 Guage - No Clean 1lb (4900-454G) **$42.00**
.032" 21 Guage - No Clean 1/4lb (4901-112G) **$7.60**
.032" 21 Guage - No Clean 1/2lb (4901-227G) **$13.40**
.032" 21 Guage - No Clean 1lb (4901-454G) **$26.00**

MG Chemicals Solder Braid

0.025" #1 White 5 ft Fine Solder Braid (423 WHITE) **$2.01**
0.05" #2 Yellow 5 ft Fine Solder Braid (424-NS) **$2.65**
0.075" #3 Green 5 ft Fine Solder Braid (425-NS) **$2.75**
0.1" #4 Blue 5 ft Fine Solder Braid (426-NS) **$2.95**
0.125" #5 Brown 5 ft Fine Solder Braid (427 BROWN) **$2.95**

Precision Mastech Bench DMM / Super Closeout!

We've found this exact Bench Top DMM selling for $149.00 at other web sites (google M9803). Super Closeout on this Precision Mastech Bench DMM. Features galore. **Sales are Limited to Stock on hand.. No back orders at this price...**

FEATURES

* Display: Digital and analog display, 3999 counts and 42 segments bar graph, digit is 18mm high
* Autorange and manual range
* Data hold, MAX/MIN relative measurement
* Storage data display/recall
* True RMS for AC voltage and current
* Back light
* ADP measurement: 400mV±0.3%, 10 DIGIT/1mV DC
* Continuity test
* Diode test
* Power source: AC or DC power supply

DC Voltage:	400m 4V 40V 400V 1000V	+/- 0.3%
AC Voltage: (True RMS)	4 40 400 750V	+/- 0.8%
DC Current:	4 40 400mA	+/- 0.8%
	10A	+/- 1.5%
AC Current::	4 40 400mA	+/- 1.5%
(True Current)	10A	+/- 2.0%
Restiance:	400 4K 40K 400K	+/- 0.5%
	4M	+/- 1.0%
	40M	+/- .05%
Capacitance:	4n 40n 400n 4u 20uF	+/- 2.0%
	20uF to 40uF	+/- 5.0%
Frequency:	100 1K 10K 100K 600KHz	+/- 0.1%
hFE:	1 to 1000	
Diode Test		
Data Hold		
MAX / MIN Recording		
Relative Display		
Auto Range		
Back Light		

Item# M9803 **$59.00**

380 watt Pure Sine Wave Inverter

* Pure Sine Wave Output
* USB 5V/500mA Supply Plug
* High temp alarm
* Output overload alarm
* Output short circuit alarm
* Low / High battery alarm
* High surge capacity for starting demanding loads

Continuous Output:	380W
Surge Output:	650W
Voltage (AC)	100V~120V
Frequency:	60Hz
Waveform:	Pure Sine Wave
Regulation (Typ.):	Vrms +/-3%
Total Harmonic Distortion:	THD <3%
USB Output(Typ.)	DC 5V +/-5% 500mA
Input Voltage:	12V
Low Battery Alarm:	10.5V
Low Battery Protection:	10V
High Battery Protection:	16V
No Load Current:	500mA
Efficiency:	>83%
Size:	240 x 119 x 60 mm

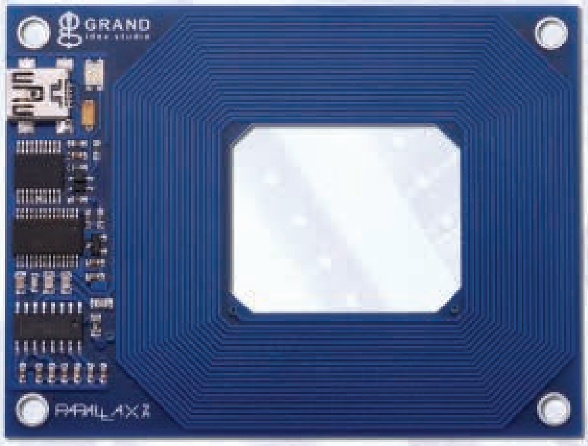
Item# SI-12038E **$129.00**

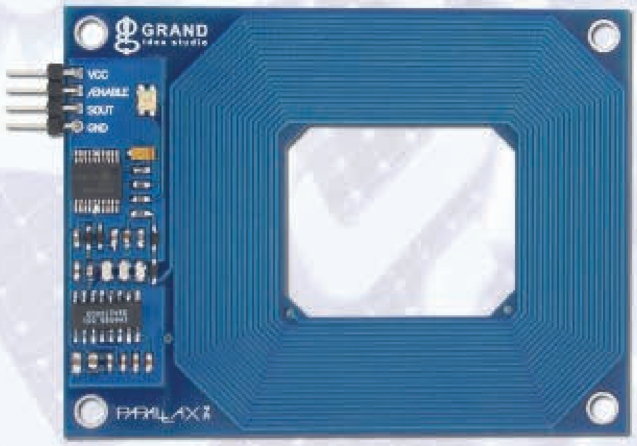
Rugged 6000 Count AutoRanging DMM

This is a very solid and versatile DMM manufactured by Precision Mastech. The MS8240C auto ranging DMM features a full scale count of 6000 and a 3 5/6 digit LCD display with 61 segment bar graph. This meter is designed to meet IEC1010-1 CAT III over voiltage protection and implements a double insulation design.

Item# MS8240C **$49.00**

Key features include:
*Push Button Min/Max reading
*Data Hold
*Relative Value (measure against a user selected reference value)
*LPF key (Low Pass Filter) to reduce the influence of high harmonics in the AC voltage & current modes)
*Back Lit display
*Hz/Duty function
*Includes deluxe set of test probes rated to 1 KV Cat III/10 Amps
*Includes Temp probe
*Includes nylon carry/storage case





RFID Reader Modules

Designed in cooperation with Grand Idea Studio, our (RIFD) Reader Modules are convenient low-cost solutions to read EM 4100 low-frequency (125 kHz) passive RFID transponder tags. The RFID Reader Modules can be used in a wide variety of hobbyist and commercial applications, including access control, automatic identification, robotics, navigation, inventory tracking, payment systems, and car immobilization. Board dimensions are 3.25 x 2.45 in (8.25 x 6.22 cm).

RFID Reader Module - USB (#28340; $39.99) - This module connects directly to a USB port both for power and to output transponder tag data to your custom PC application. A sample Visual Basic (VB.net) application is provided on the 28340 product page. *Features include:*

- Built–in USB interface for easy connection to your PC
- 2400 baud serial output stream to PC is accessible from any programming language that can open a COM port
- Transponder tag ID data given as a 12-byte ASCII string
- Bi-color LED for visual indication of activity
- Power required: 5 V (USB connection); 10 mA idle, 90 mA active

Note: a USB A to Mini-B cable is required, sold separately (#805-00006; $3.99). Several transponder tag styles are available from Parallax, www.parallax.com.

RFID Reader Module - Serial (#28140; $39.99) - This 4-pin module is designed for easy prototyping and integration into stand-alone microcontroller-based applications. Parallax provides sample code in PBASIC and SX/B on the 28140 product page. *Features include:*

- 4-pin 0.1 inch SIP header for power, ground, enable, and data-out connections
- 2400 baud TTL serial output (81N) to any Parallax microcontroller
- Transponder tag ID data given as a 12-byte ASCII string
- Bi-color LED for visual indication of activity
- Power required: 5 VDC; 10 mA idle, 90 mA active

We also offer the RFID Reader Modules as part of sampler kits which include an assortment of four RFID transponder tags.

RFID Reader (USB) and Tag Sampler Kit (#32395; $42.99; right)
RFID Reader (Serial) and Tag Sampler Kit (#32390; $42.99)

Order **RFID Reader Modules** at parallax.com
or call our Sales Department toll-free at 888-512-1024
(Monday-Friday, 7 a.m. - 5 p.m., PDT).

PARALLAX INC
www.parallax.com
Friendly microcontrollers, legendary resources.